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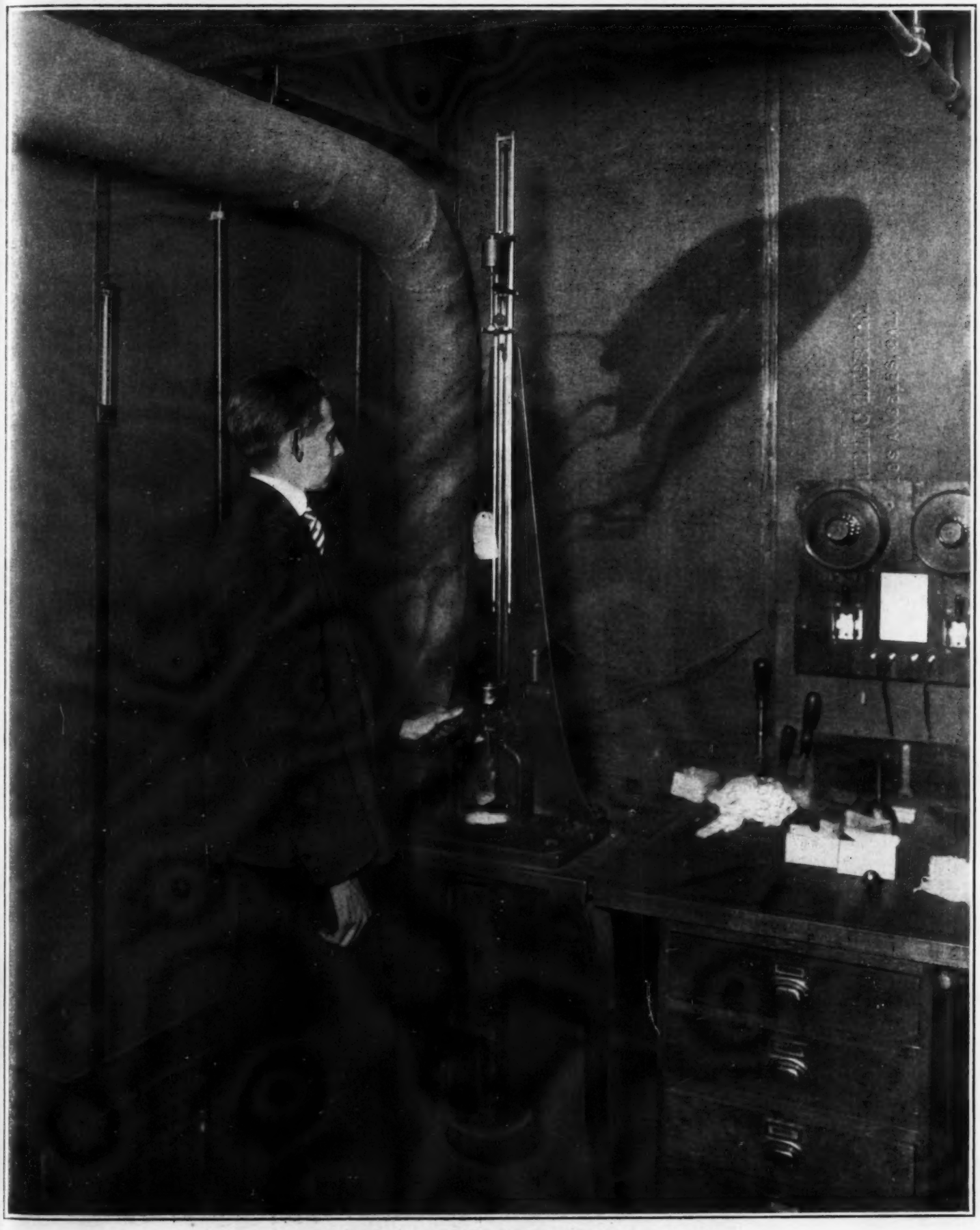

Primer Testing Machine.—Determining the Sensitiveness of Primers and Mixtures

TESTING RIFLE AMMUNITION.—(See page 221)

The Langmuir Postulates–I*

An Intruduction to Dr. Irving Langmuir's New Theory of the Constitution of Atoms and Molecules

By Ellwood Hendrick

THE address of Dr. Irving Langmuir delivered at the Buffalo meeting of the American Chemical Society on "The Arrangement of Electrons in Atoms and Molecules" made such a deep impression upon those who heard it, and the potentialities of the Langmuir postulates loom so large as applied to research, that we resolved to give our readers a report on the subject as soon as this could be made ready. The first original paper appeared in the June number of the *Journal* of the American Chemical Society. Owing to the intense concentration of the text it is not easy reading, even to the average chemist, and in what follows we shall not attempt to cover the field with thoroughness, or even to touch upon problems that require experience in applying the postulates. Our purpose is to write an introductory chapter, and to begin "further back" for the benefit of those who have not followed diligently the voluminous literature of research on the structure of atoms and molecules. We shall not even attempt to make clear between the Langmuir postulates and the work of other men in research whose conclusions are in part accepted. We are dealing with a new philosophy of chemistry which differs from that of the present text-books in various concepts, but which provides a definite means of determining upon the arrangement of atoms in combination, as well as that of electrons in atoms and molecules.

PRACTICAL VALUE OF THE THEORY.

We shall try to give at least a glimpse of its amazing practicality when applied in the laboratory. It is, in effect, a new angle of attack which calls for new mental processes; and, as with any new tool, these seem difficult at first. When we state, however, that with adequate understanding and experience, it becomes possible to predicate the physical and chemical qualities of a substance, even to its crystalline structure, before it is synthetized; that it opens up a new and workable theory of valence; that it explains the curious manifestations of the elements of the rare earths and other elements in the periodic table, the irregularities of nitrogen, and the magnetic properties of the iron and platinum groups of metals, as but a part of its contributions, we need give no further emphasis to its value as an aid to technology as well as to research. We shall not undertake to make all these facts clear. Our purpose is to lure the reader into a consideration of the subject, so that he may approach Dr. Langmuir's present and future papers with that quality of interest which is warranted by their importance.

For lack of space and with a view of confining ourselves to the simplest features in this article we shall omit discussion of the principle involved in the secondary planes (Postulate I) in connection with the position of electrons in atoms of greater complexity, also the magnetic forces as indicated in Postulate V, and the illumination shed upon the great work of Werner, and refer the reader to the first paper in the June number of the *Journal* of the American Chemical Society for the explanations and a much more comprehensive discussion of the entire subject in a very condensed form.

We are indebted to Dr. Langmuir for a number of extended interviews, and we express our sincere obligations to him for his patience in exposition.

STRUCTURAL RESEMBLANCE OF N_2O AND CO_2

By way of indicating the workings of the theory let us take as an example two gasses that we have not heretofore regarded as having any qualities in common: N_2O, or laughing gas, and CO_2. According to the Langmuir postulates, as we shall try to develop them in part, these gases display a remarkable resemblance in the structure of their molecules, containing each the same balanced number of positive and negative charges, and the same exterior arrangement of electrons, so that, were they magnified to visibility, and the kernels of the atoms hidden from view, we should be unable to tell them apart by looking at them. At least it is a fair guess that by looking at them, under these conditions, we should be unable to distinguish them, one from the other. Then we conclude that they must have certain physical properties in common. The figures which follow have not been published elsewhere at the present writing; we are indebted for them to Dr. Langmuir, who will present them later on with detailed explanation in the *Journal* of the American Chemical Society, but they will serve to indicate the points of remarkable similarity in the physical properties of two gases which Dr. Langmuir concludes to be similar in structure. The records are taken from unrelated pages of published works:

	N_2O	CO_2
Critical pressure, atmospheres	75	77
Critical temperature, deg.C	35.4	31.9
Viscosity at 20 deg.C	148X10-	148X10-
Heat Heat conductivity at 100 deg.C	0.0506	0.0506
Density of liquid at —20 deg.C	0.996	1.031
Density of liquid at 10 deg.C	0.856	0.858
Refractive index of liquid, D line 16 deg.C	1.193	1.190
Dielectric constant of liquid at 0 deg.C	1.598	1.582
Magnetic susceptibility of gas at 40 atmos., 16 deg.C	0.12X10-	0.12X10-
Solubility in water, 0 deg.C	1.305	1.780
Solubility in alcohol, 15 deg.C	3.25	3.13

Both gases form hydrates, $N_2O.6H_2O$ and $CO_2.6H_2O$. The vapor pressure of the hydrate of N_2O is 5 atmospheres at 6 deg. C., while the hydrate of CO_2 has this vapor pressure at —9 deg.C. The heats of formation of the two hydrates are given respectively as 14,900, and 15,000 calories pergram-molecule.

The surface tension of the liquid N_2O is 2.9 dynes per sq.cm. at 12.2 deg., while CO_2 has this same surface tension at 9.0 deg.C.

FIG. 1 FIG. 2 FIG. 3

Helium Neon

Thus N_2O at any given temperature has properties practically identical with those of CO_2 at a temperature of 3 deg. lower.

These results indicate the similarity of the outside structure of the molecules.

DISAGREEMENT IN FREEZING POINT.

There is one property, however, that is in marked contrast to those given above: the freezing point of N_2O is —102 deg.C. while that of CO_2 is —56 deg. This may be taken as an indication that the freezing point is a property which is abnormally sensitive to even slight differences in structure. The evidence seems to indicate that CO^2 is slightly more symetrical and has a slightly weaker external field of force than that of N_2O.

It would be hard to find such an array of coincidences unless there were reasons for them, and it is one of the purposes of this paper to show reasons for them, as we proceed.

All of these figures have been gathered by painstaking research in the past. They were uncorrelated and uninteresting. But in the light of this theory we find them ranging themselves into such subtle correlation as to cause them to function as parts of that greater whole which men of research are ever trying to discover. For decades these figures have been available. But in this case, as in that of other bodies which we shall consider later, the identical physical characteristics of those of like structure have remained unobserved.

II

At the end of the paper we present the postulates upon which the work is based, and we shall refer to them from time to time as we proceed. But, going "further back," as we promised to do, let us consider every atom as made up of two component parts: the electro-positive charges concentrated in the nucleus of each atom, which is individual and peculiar to each element, and the electrons which are electro-negatively charged, and which, from their positions about the nucleus, neutralize the positive charges on it. *The electrons are arranged in a definite configuration about the nucleus of each atom.* They are not of necessity held absolutely still. There is no reason why they may not move about, but the area of activity of each electron that forms a part of an atom is circumscribed within limits of space similar to that of its neighbor. Unlike the nuclei which, as we have just said, are held to be peculiar to each element, we consider the electrons to be all alike.

Now let us bear in mind the atomic numbers of the elements in the order of their atomic weights in the periodic table. They are: H, 1; He, 2; Li, 3; Be, 4; B, 5; C, 6; N, 7; O, 8; F, 9; Ne, 10; Na, 11; Mg, 12; Al, 13; Si, 14; P, 15; S, 16; Cl, 17; Ar, 18; K, 19; Ca, 20; Sc, 21; Ti, 22; V, 23; Cr, 24; Mn, 25; Fe, 26; Co, 27; Ni, 28; Cu, 29; Zn, 30; through to U, 92.

ATOMIC NUMBER COINCIDES WITH ELECTRO-POSITIVE CHARGES.

Thanks to the brilliant Moseley of Manchester, England, killed as a private soldier in the flower of his youth in the Gallipoli fight, we have confirmation of the statement that the atomic number of each element in the periodic table and the number of electro-positive charges on the nucleus of its atom are the same. Thus from the above we read that the number of positive charges on the nucleus of the hydrogen atom is 1; that of the lithium atom is 3; carbon, 6; nitrogen, 7, and so on, so that the table of atomic numbers is also that of the positive charges on the nucleus of the atom of each element. From this we gather also that the nucleus of the atoms of no two elements can be the same, and we learn, too, that the table of atomic numbers gives, in addition to the foregoing, the number of electrons that are attached to, and form part of, every atom of every element. There must be an electron to neutralize every positive charge, because the difference between an atom and an ion is that in the former every positive charge of the nucleus is satisfied with an electron, and is therefore neutral, while in an ion this is not the case. In an ion there are either more or fewer electrons than will completely balance the positive charge of the nucleus of the atom, or the nuclei of the atoms, which constitute it.

In acknowledging and accepting in part certain theories of W. Kossel and G. N. Lewis, Dr. Langmuir carries them further, with various changes and extensions, but, as already stated, for the sake of brevity we shall not attempt to indicate the specific authorship of each idea.

III

By themselves electrons repel each other, but in the presence of positive charges they show a disposition to arrange themselves into definite groups; they indicate a law, or series of laws, of configuration, and this is the first step in the present work. If, then, these groupings, these configurations, may be found complete in the most stable of the elements, and incomplete in others, we may infer that in the inert gases the electrons are satisfied, that they have fulfilled their tendency to conform to certain arrangements, and that the activity of other elements is due to the drive to confrom as nearly as possible to the complete, and therefore inert, elements. The author of these postulates will have nothing to do with metaphysics in the development of his theories of the constitution of atoms and molecules, but we cannot resist the observation that in this pair-forming and octet-forming nature of electrons about positive charges we find suggested the tendency in nature toward a condition of balance and rest which is the basis of the great postulate of Gautama Buddha, and the substance of the ancient philosophy of the East.

HELIUM THE MOST STABLE ELEMENT.

Different elements do not behave the same; they differ in their nuclei and in their arrangement and number of electrons, but in this striving to become as nearly as possible like the fixed gases we find the

*From *Chem and Metall Engineering* (New York).

TO OUR SUBSCRIBERS

We are laboring under great difficulties on account of the strike of compositors and pressmen. Through no fault of ours the publication of the SCIENTIFIC AMERICAN SUPPLEMENT *has been seriously hampered, but despite all handicaps we are endeavoring to continue issuing this journal. Obviously our normal schedules cannot be maintained, and until the strike is ended publication of the* SUPPLEMENT *will necessarily be much delayed. This week we are offering you a double number, combining the issues of October 4th and 11th. We beg your indulgence in these trying times. We are doing everything in our power to serve your interests.*

key to all chemical phenomena. It behooves us, therefore, first to consider the most stable element, which is helium. The atomic number of helium being 2, the positve charge of its nucleus is 2, and it has two electrons. How are these arranged? There being but two they cannot follow an isometric system: the simplest would be the tetragonal system, having, like the earth, a polar axis and an equatorial plane (Postulate I). We imagine these two electrons as held by the positive charges of the nucleus very much as though the nucleus were in the center and the electrons each in the half of a complete shell, say, like a walnut-shell, that surrounds it. Neither electron crosses the plane which divides these two hemispherical shells. We might picture, as in Fig. 1, a cross section of the helium atom, cut a little above the equator, so as to show all charges, the positively charged nucleus indicated by ++ and each of the electrons by a — sign.

IV

This must be the most permanent arrangement of electrons about a nucleus: one electron in each half of a spherical shell, and neither trespassing upon the territory of the other. And while there is no reason to regard the electrons as stationary, save that each keeps within what we call its cell, it will be convenient for us to consider each as occupying its average position, which would be on an axis perpendicular to the plane which divides them. Here we have a complete satisfaction of the positive and negative charges with almost no force extending beyond the atom in any direction. Let us say the electrons have achieved a position of complete balance and contentment, thus making helium the most permanent substance known. Because there is practically no external force about the atoms, and the primary disposition of its electrons to form pairs is satisfied, the atoms do not form molecules; they remain independent and inert. So independent and inert are they that not only is He a gas, owing to the lack of external force about its atoms, but these atoms are readily separated, and its boiling point is therefore only 4½ degrees above absolute zero. We have, then, in helium, the achievement of the first electronic ideal: the grouping in pairs about a positive charge. Such a central part we consider to be common to all atoms except that of hydrogen: the nuclei varying from 2 to 92 positive charges, according to the element, and the first pair of electrons invariably next to the nucleus.

V

The next element to helium in point of stability is neon. Its atomic number being 10, we must find an ideal arrangement of its ten electrons. The nucleus has ten positive charges, and the conclusion is that the first pair group themselves about the nucleus, just as in helium, leaving eight positive charges to be satisfied. These eight electrons arrange themselves in a second shell outside that containing the pair, four in either hemisphere of the outer shell, and each in its own cell. A top view would appear as in Fig. 2, with the nucleus and pair hidden under the outer shell. A perspective view would be as in Fig. 3. These eight electrons, four in either hemisphere of the outer shell, we call an octet. This shell is twice the diameter of that including the pair below it, and its surface is four times as great. This is in order to give the same space or room to each cell. There are eight cells, and every cell in the outer shell of neon is occupied. Now since we hold that chemical activity emanates mainly from the outer shell of electrons, there is no occasion for chemical activity in neon. And bearing in mind this greater chemical activity of the outermost shell we shall follow G. N. Lewis in calling all that part of any atom that is within the outer shell, its *kernel*. The second disposition of electrons is to group themselves into octets, and here they have done it. We have a pair, and an octet, all balanced, all filling every available space, and so there is no chemical activity to neon. It is inert; it is a gas; it has a low boiling-point, and it does not form molecules. It is completely satisfied as it is, and next to helium it is the most stable element. The next element in order of stability is argon, atomic number 18. This is just like neon, except that, according to Postulate IV, each cell of the second shell contains 2 electrons, making 2 in the first and 16 in the outer shell. This is also a permanent gas. In krypton, atomic number 36, we have two in the first shell, 8 + 8 in the second, and have 18 still to dispose of. The third shell will contain 18 electrons; 9 in each hemisphere. One of these 9 electrons will go to the pole, and the remaining 8 will be distributed symetrically about it. The same thing happens in the other hemisphere. With xeon we have krypton as the kernal (except that the nucleus has 18 more positive charges) and the 18 more electrons are distributed in the same manner in the third shell, making 2 in each cell, and including one more in a cell at each pole. Niton follows as the last, with 32 electrons in the fourth shell, 16 in each hemisphere.

In other words, we assume these inert and stable elements to be made up of successive and consecutive groups of electrons about the nucleus of each, consisting of first the nucleus, next a pair of electrons, and then consecutive octets and double octets with a pair in the polar position whenever there is an odd number of electrons to be provided for in each hemisphere. According to Postulate IV, all inner shells must have their full quota of electrons before the outer shell can contain any, but we note that in the inert elements the outside shells have their full quotas also. *This is the very reason for the stability and inactivity of these elements;* the electrons are ideally placed, they are electrically balanced, there is a minimum field of external force about the outer shells, therefore they all are gases, and have low boiling points.

No element other than the inert gases has its outer shell satisfied, i. e., every cell of its outer shell occupied, and therefore the electrons in the outer shell are always striving to make pairs of octets with some other electrons. *This is the basis of all chemical combination and reaction.* We shall try to make this more evident as we proceed.

VI

When we consider hydrogen, atomic number 1, we have but a single charge and a single electron. We have not even a pair. The lone electron is ever trying to form a pair, and therefore the atoms pair off in molecules. Note, please, in Postulate VI that a stable pair may be held by two hydrogen nuclei. Of course the hydrogen molecule is not as stable as an inert gas but compared with a single hydrogen atom which

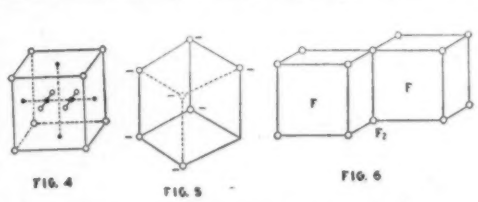

FIG. 4 FIG. 5 FIG. 6

Nitrogen Molecule **Fluorine Atom (5) and Molecule (6)**

has an exceedingly short time factor for its separate existence, the hydrogen molecule is very stable. It has the lowest boiling point of all substances except He, being but 20 deg. absolute. Due to such complete saturation within itself its external force is slight, and it shows slight chemical activity until it is split up into atoms. The old *status nascendi* theory in regard to hydrogen worked well in that it referred really to unpaired hydrogen atoms. If we take from a hydrogen atom its single electron we have left of course the hydrogen ion.

Lithium with its atomic number of 3 has three electrons, of which two form a pair about its nucleus and which constitute the lithium ion, while the third is easily detached, because it tends to form pairs or octets. We read in Postulate VI that the two atomic kernels can very rarely hold a pair of electrons as is the case with the H molecule. The lithium kernel already has its pair, and therefore it cannot get another nucleus into its kernel. The lithium atom with but one electron in its second shell produces a strong electrostatic field which extends into surrounding space. There being no free nuclei about which the single outside electrons can group themselves into pairs or octets, it is electrostatic force which holds the atoms together, a second upon the first, a third upon the second, a fourth upon the third, and so on, *ad infinitum*, so that it appears to build itself into a solid lattice work structure. Therefore it is a solid. It melts and boils with difficulty. Because of the free electrons it is a good metallic conductor, but for lack of enough available electrons to form octets on the outer shell it has no tendency to form molecules either in a solid, liquid or gaseous state.

PROPERTIES OF FLUORINE IN THE LIGHT OF THE THEORY.

Fluorine has the atomic number 9, or one less than neon, so that it has a pair about the nucleus and seven in its outer shell, lacking but one electron to make the octet complete. The cumulative effect of its seven outside electrons to form an octet is so great as to give it intense chemical activity. If brought into contact with lithium it takes the electron from it and completes its octet, making the fluorine ion negatively charged, and leaving the lithium ion positive. Let us repeat this to make it clear. Fluorine has nine positive charges on its nucleus, and about it is, first, a pair of electrons, and then seven more in its outer shell. With seven electrons all placed in a shell with eight cells, and all seven trying to form an octet, the effort is likely to be intense. And it is. Nobody ever called fluorine inert! That lone extra electron of lithium in an outer shell (although, of course, the concept of shells and cells is a concept of space only) is pulled over to the vacant space in the fluorine outer shell. That leaves the lithium ion free. But with nine positive charges on the nucleus of fluorine and ten electrons now engaged, the fluorine ion becomes negatively charged because of ten electrons about its nucleus with + charge of 9. So too the lithium ion, which has a triple positive charge on its nucleus and has lost an electron, has now but two instead of three negative charges, which makes the lithium ion positive. The force, however, which holds this ion to the fluorine ion with its octet of electrons is electrostatic; there is no opportunity for pairs of electrons to be held in common by the two elements, therefore there is no LiF molecule. Every lithium ion is attracted to all the negative fluorine ions about it, and *vice versa*, so that it builds up a lattice work of the two ions, as in Bragg's salts. It is a solid, but it is a non-conductor, because there are no free electrons, every octet being satisfied. If, however, we melt it, then it becomes an electrolytic conductor, because the ions are then free to move around.

RELATIVE CHEMICAL ACTIVITY OF HALOGENS.

Here is an illuminating note which explains why the halogens decrease in chemical activity as they increase in atomic weight, and therefore in atomic number, while with the alkali metals the opposite is the case. Not only does fluorine stand next to neon, but all the halogens stand next to the inert gases, each having one electron less. Chlorine bears this relation to argon, bromide to krypton, and iodine to xenon. But as these inert gases increase in atomic number they become less stable, as is indicated by their decreasing ionization potentials and their increasing boiling points. There is greater distance or greater interruption between the positively charged nucleus and the negatively charged electrons in the outer shell as atomic numbers increase. Therefore it stands to reason, among the halogens, that as they increase in atomic number their electro-negative qualities decrease in intensity. On the other hand lithium stands next to helium, and the other alkaline metals bear a similar relation to the inert gases, each having one electron more rather than one less, as with the halogens. This lone electron on the outer shell is given up in the presence of a positive charge; it cannot well draw on seven other electrons to complete the octet. But the electrostatic force between the nucleus and the outermost electron becomes less and less as the kernal grows larger and larger, because the distance between the positively charged nucleus and the outermost electron becomes greater. Therefore the outermost electron becomes more readily detachable as the size of the atom increases, so that sodium is more electro-positive than lithium, while potassium is more electro-positive than sodium.

Carbon, atomic number 6. Here the atom is composed of a pair of electrons about the nucleus, and four in the outer shell. By virtue of the larger charge in the kernel these are not easily given up, as in lithium, but may be regarded as constantly trying to draw on four more electrons to make up an octet. The atom is symmetrical, and its tetravalency is persistent. Its well balanced but incomplete structure explains both its permanency in combination and its high boiling point.

(*To be continued*)

Graphic Ammeters

The modern graphic ammeter is lighter, cheaper and more easily used than semi-portable graphic wattmeters, and, although the latter are more accurate, the graphic ammeter is sufficiently accurate for many industrial purpoaes. A graphic ammeter connected in a motor circuit shows at what time the motor was started and stopped; and also gives the power consumption at no-load and when loaded. The instrument also shows the number of operations performed by the machine driven and whether the machine is being operated correctly and at maximum production. —Abstracted by *The Technical Review* from *Power* (New York).

From *"L'Illustration"* (Paris). Photo by Kurkdjian

VIEW BORDERING THE CRATER OF KALUT VOLCANO

On May 20, 1919, the volcano deluged the whole region with floods of hot mud and took a toll of 7,000 victims. The crater filling with boiling mud overflowed in three directions, destroying rubber and coffee plantations and overwhelming the town of Blitar as well as many villages. A rain of ashes and stones rounded out the work by the mud streams. This view was taken by an exploratory commission 2 days after the eruption.

Airplane Mapping by the United States Army

Yankee Airplane Mappers Studying and at Work; a War-Time Accomplishment Suited to Days of Peace

THE accompanying views, recently released by our Government officials, though made during war time activities and training periods, serve as equally true illustrations of the different steps and methods of procedure in airplane mapping advocated by Superintendent E. Lester Jones of the U. S. Coast and Geodetic Survey. Readers of the SCIENTIFIC AMERICAN SUPPLEMENT will recall the admirable address by Colonel Jones, which we published in the issue for June 21 last (No. 2268). In that contribution he pointed out that our coast charts need steady revision in many sections because of the relatively rapid changes in depths, culture and shoreline, and brought out the point that—where there is no detailed contouring to be drawn in—shifts in shoreline or alterations in culture can be much more economically secured by airplane photographic mapping than by painful foot or boat surveying by the more usual traverse methods. The airplane mapper will also be a very valuable assistant acting independently as reconnaissance and first-approximation mapper in territories not yet mapped at all; and as soon as a good primary triangulation net is run into such a region the airplane photographs will be valuable as material on which to reconstruct the airplane reconnaissance map on a more accurate foundation. It may be assumed that this reconnaissance work will be part of the first task set the peace-footing airplane cartographers as there are yet remaining to be surveyed nearly three-fourths of the area of the United States. So great a part of our own 20-Century America is yet without maps whose accuracy is sufficient to make them useful and reliable for the engineers charged with modern enterprises and industries. Another need, most modern in its nature and not accented by Colonel Jones, is the growing one of navigation maps for aviators across and along this country. Such maps are indispensable for inter-State and Transcontinental air-mail and air-passenger-freight lines now in course of development; and such maps must be prepared from the point of view of the air-man, not of the automobilist. It seems reasonable to conclude that the air-man's maps will be best made by the air-man's topographic surveyor rather than by his first-lieutenant, the topographer on terra firma.

Learning how to center important objects when flying high and it is impossible to focus.

Assigning the day's work to the Airplane Photographer, by means of an ordinary map

A United States mapping camera being fastened in place, and reserve magazines of plates going aboard

Motorcyclist retrieving a package of just exposed plates sent down by Parachute

Our photographs start with a view of prospective airplane mappers learning how to interpret airplane movement and ground appearance simultaneously so that they may secure the views they desire while flying and therefore working with a camera which must be pointed by the airplane itself, not by a man working from a fixed tripod as on the ground. This art of aiming the airplane camera accurately and timing the release to catch the object aimed at is one requiring some experience and skill. Having secured the sets of photographs—some of them in stereoscopic relation to each other, as suggested and explained in our recent illustrated contribution, *Progress in Aerial Photography* (SUPPLEMENT No. 2278, for August 30, 1919)—the next problem is to "read" the photographs correctly, that is, we must learn to translate the little dots, squares, and wiggles into houses, hills, streets and roads, streams, hills, trenches and valleys. Our first photograph shows some of the army students engaged in this translating by the aid of relief models of the objects photographed.

That the day's work may be profitable and fit properly into what has gone before and what is to follow, much planning is always necessary; our second view shows the last hour's consultations and understandings before the day's flights begin. While at the same time behind the avion the photographer and his assistants are busy placing the camera in its brackets (for other types of airplane camera see SUPPLEMENT No. 2278) and stowing the ready-loaded automatic-feed magazines of dry plates required for the contemplated reconnaissance. This is shown by our third view.

During field war service it was of the greatest importance to get the exposed plates from the plane to the developing room and the results to the staff officers as quickly as possible. Thus there was developed the type of quick despatch illustrated by the lower lefthand photograph. Here we see that the aviator has dropped his newly exposed magazine charge, by means of a parachute, and that the load has been successfully chased by the motor-cycle lookout, who is in the very act of seizing it from the air. The cyclist will now hurry the magazine to the field dark room shown on the right and there prompt development and profing will put the army into almost instantaneous possession of what is going on in No Man's Land. The same system, with less violent rush perhaps, will undoubtedly be developed into useful lines for the aerial topographic party chiefs. Should some part of the course have failed to receive the desired attention the chief will learn it promptly and wireless telephony will permit the chief of party to direct the photographer to the desired area again.

We are quite justified in expecting not only novel and interesting developments for the lover of the exciting and the curious, but also of methods and results that will be valuable to map maker, geographer and exploiter of resources. Airplane maps of the Arctic and the Antarctic regions are quite within the scope of possibilities and would yield information of the greatest interest to sportsmen as well as scientists. Again airplane mapping of some known rich but little explored region may well reveal waterways, water powers, and avenues of approach or egress that would prove most valuable to a company fit to undertake the development of that district. Such maps can be prepared long before it will be possible to penetrate and explore in detail on foot the regions considered.

The retrieved plates are hurried to the field "dark room" for development (Present view of a camouflaged truck in France)

Present Position of the Nebular Hypothesis*

Tests of Laplace's Hypothesis Reveal Its Power for Interpreting Many Celestial Formations

By Prof. J. H. Jeans, Trinity College, Cambridge

AMONG scientific speculations, the Nebular Hypothesis holds, and for over a century has held, a unique position. It is unique in its absorbing interest and in its world-wide fame—these are mere commonplaces. It is unique also in the remarkable longevity of its speculative aspects. Put forward in 1755 by Kant, and again independently in 1796 by Laplace, it is still in 1918, in the opinion of most astronomers, a speculation which has been neither proved nor disproved. Such a length of life, although it would be small for the speculations of metaphysics, is almost unparalleled in natural science. The fundamental reason for this great length of life will perhaps be found in the extreme difficulty of obtaining either observational or theoretical tests of the truth of the hypothesis.

In the more definite form in which it was left by Laplace, the hypothesis dealt only with the genesis of the solar system, and the origin of the systems of planets and satellites composing it. A hot nebulous mass of gas is supposed to be flattened in shape as a result of rotation, and to shrink continually as it cools. In accordance with the principle of conservation of angular momentum the diminution in size must be accompanied by a continual increase in the velocity of rotation. When the rotation has reached a certain speed, centrifugal force will, according to Laplace, outweigh the gravitational attraction of the mass at its equator, and the result is supposed to be that a ring of matter is thrown off from the equator. Thus, if we accept Laplace's beliefs, the primitive nebula becomes in time surrounded by a system of rings somewhat similar to the rings of Saturn, and these finally agglomerate into planets. As the shrinkage still continues, the same sequence of events occurs to these planets, so that we finally find them surrounded by satellites.

Such a hypothesis admits of being tested in two ways, by observation and by mathematical research. Laplace may perhaps have hoped that the telescopes of the future would reveal numerous systems of stars in different stages of evolution, so that the life history of such systems could be deduced. And the Nebular Hypothesis might be considered proved with sufficient rigor, if we found in the sky systems in the various stages described by Laplace, ending up with a great number of systems similar to our own. So far from this being the case, observational astronomy has so far failed to discover a single other stellar system which is in the least degree similar to our solar system, or which seems in the remotest degree likely to develop into such a system. This may perhaps be due to the limitations of our instruments, but the fact remains; the attempt to test the theory observationally leads at the best to a closed door.

There are no such limitations to the possibility of testing the theory by mathematical research. The properties of a gas are well known; the dynamics of rotation are fully understood. The mathematician may accordingly be asked to discover what sequence of configurations would be assumed by a mass of rotating gas, shrinking gradually as it cooled. It is a fair problem to propound to him. If he cannot solve it his excuse cannot be the limitations of the power of telescopes; it can only be the limitations of the human mind. And yet, so intricate is the problem that, in spite of its extreme interest and fundamental importance, it still remains only partially solved.

We can understand some of the intracacies of the problem by considering a much simpler terrestrial problem. The surface of the ocean, as we know, is approximately spheroidal in shape. The vertical at any point is determined by the direction of the resultant of two forces—centrifugal force arising from the earth's rotation, and gravity arising from the joint attraction of the earth and sea. And the surface of the sea is determined by the condition that this resultant shall act perpendicularly to the surface at every point.

Fortunately for the geodesists, the earth and sea form together a nearly spherical mass, and there is no difficulty in writing down the gravitational attraction of a nearly spherical mass. But in the cosmogonic problem, the matter stands very differently. The rotating mass of gas is of unknown shape, and the variations of density are unknown; clearly the difficulty of calculating the gravitational attraction will be very great.

Naturally enough, then, the first attempts to solve this problem were limited to a simplified ideal problem, in which the simplest conditions were assumed; the real astronomical matter was supposed replaced by homogeneous and incompressible matter so that all complications arising from variations of density were avoided. Even this simplified problem has taxed the skill of some of the most eminent mathematicians— among those who have worked at it may be mentioned Maclaurin, Jacobi, Lord Kelvin, Poincaré and Sir G. Darwin. After much labor, the sequence of events in a rotating mass which shrinks while remaining always homogeneous is fairly well established. When the mass is of low density so that its rotation is slow, its shape differs from a sphere only in being slightly flattened or orange-shaped; it is an oblate spheroid of small eccentricity. As shrinkage proceeds and the speed of rotation increases the flattening increases in amount, but the figure retains an exact spheroidal shape until a stage is reached at which the axes have a ratio of about 7:12:12. At this stage the somewhat disc-like figure which has been reached exhibits a tendency to crumple up about one of its equatorial diameters. It is accordingly found that further shrinkage leads, not to a still more flattened spheroidal figure, but to an ellipsoidal figure. The ellipsoid has its two longer axes equal at first, but as shrinkage proceeds the ellipsoid becomes more and more elongated until a somewhat cigar-shaped figure is reached having its axes in the ratio 6½:8:19. A tendency now appears for a furrow to form near, but not actually across, the middle of this cigar-shaped ellipsoid. The ellipsoid, deformed by such a furrow, forms the celebrated pear-shaped figure of equilibrium, of which the existence was first demonstrated by Poincaré, and which has been the subject of elaborate mathematical research by Poincaré, Darwin, Liapounoff, and others. It has now been established that these pear-shaped figures are unstable; the sequence of events when once the pear-shaped figure is attained appears to be that the furrow forms rapidly and deepens until the rotating mass finally divides into two detached portions. It appears fairly certain that these masses, although unequal, would approximate to equality in size, but this has not been rigorously proved.

This fission into two detached masses is of course not the end of the story. Each body into which the original mass has divided is itself a shrinking and rotating mass; the sequence of events already described may be expected to repeat itself. This last chapter of the story has been sketched out by Prof. H. N. Russell. In brief Russell has shown that the larger of the two masses must break up first, and that the distance apart of the last pair formed will be small compared with that between this pair and the companion-star.

The importance of this is as follows: In the sky there are thousands of binary and multiple stars—Jonckheere's recent catalogue alone contains 3,950. In most cases the telescope reveals merely two stars revolving about one another. In about one case in ten, the star, when examined under a telescope of sufficient resolving power, proves to be a triple system. And Russell finds, as the result of a statistical discussion, that those triple systems in which the separation is not above a certain limit (about 1,000 years proper-motion) show just those characteristics which his theoretical investigation showed to be necessary in a system which has broken up under increasing rotation.

Thus Russell's investigation leaves little room for doubt that the ordinary binary and multiple systems found in the sky have been formed by the action of rotation on a continually shrinking mass. But the whole mechanism of breaking up is, as we have seen, very different from that imagined by Laplace, and the final product is, if possible, still more different. Of all the multiples and binary systems known, not one shows any resemblance to the solar system.

It will not, however, have been forgotten that Laplace postulated a primeval nebula of extreme tenuity and of the compressibility of a gas, whereas the mathematical investigations we have been considering have assumed the matter under discussion to be absolutely incompressible and homogeneous. Clearly we are not yet in a position to pronounce against the Nebular Hypothesis. There is a possibility, and indeed even a probability, that the sequence of events in a tenuous compressible mass will be very different from that in a perfectly incompressible mass. We have, so to speak, discussed so far only what happens to a rotating mass of water; to test the nebular hypothesis we must examine the behavior of a rotating mass of gas.

One feature which is essentially present in a mass of gas or other compressible matter in equilibrium under its own gravitation is not reproduced at all in the incompressible mass—namely, the increase of density towards the center. The exact law of increase is naturally a subject for mathematical discussion; it is found to depend on the temperature gradient and this in turn will depend on the origin and past history of the mass. The complete problem here presented is so complex as to be quite beyond the reach of mathematical analysis at present. Only approximate solutions are available.

As far back as 1855, Roche discussed the extreme limiting case of matter so compressible that practically the whole mass may be supposed concentrated close to the center of gravity, the outlying parts forming merely an "atmosphere" of density negligible in comparison with that of the central region. For the mathematician this simplified problem has one great attraction; whether the mass is rotating or at rest, the gravitational force from the whole mass is the same as that from a heavy particle situated at the center, and this can be written down at once. It accordingly becomes a simple matter to investigate what figures will be assumed by the boundary of the "atmosphere" as it shrinks and the rotation increases. With slow rotation, it is found that the boundary will be a spheroid, just as for a mass of incompressible matter. With increasing rotation the spheroidal form is departed from and a lens-shaped figure takes its place. Roche found that when a certain critical velocity is reached this lens-shaped figure develops a perfectly sharp edge round its equator, the figure of the boundary being at this stage very approximately that of a symmetrical double convex lens of thickness equal to two-thirds of its diameter. This critical velocity having once been attained, any further increase of velocity produced by further shrinkage does not result in a further change of shape; it results in matter being ejected from the periphery of the lens, while the lens retains its shape but of course with diminishing size. This is almost precisely the course of events predicted by Laplace.

But is Roche's artificial model likely to represent faithfully the events in an actual mass of gas? For in an actual mass the central condensation is of course nothing like so pronounced as that imagined by Roche. Indeed in this respect an actual mass of gas will hold an intermediate position between the model of Roche in which the central condensation is extreme, and the incompressible model studied by Poincaré, Darwin, etc., in which there is no central condensation. We might reasonably expect its behavior also to be intermediate between that of the two models, but this proves not to be the case.

Some mathematical investigations I have recently undertaken indicate that the model of Roche will give an extraordinarily accurate representation of the behavior of actual gas so long as the density of this gas is low—roughly speaking, less than about a quarter of that of water. But at a critical density of about a quarter of that of water, a sharp and sudden change occurs, and for densities higher than this, the motion of a rotating gas approximates very closely to that of an incompressible mass.

There is general agreement among astronomers that in the general trend of evolution, matter increases in density. In its youth astronomical matter is of low density; in old age, it is of high density. Thus young masses of matter in rotation will break up in the way pictured by Laplace. Old matter will break up in the manner shown to us by Darwin and Poincaré.

We have already discovered visual evidence of the reality of the latter method of break-up in the systems of binary and triple stars observed in the sky. And these, as they ought to be, are *old* matter in our sense of the term; their density generally speaking, is above a quarter of that of water. Doubtless, as Rus-

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sell and Shapley have shown, there are double stars of densities much less than this, but they are somewhat exceptional. Campbell's investigations on spectroscopic binaries suggest that stars begin, as a general rule, to break up just about when they attain to what we are calling old age—when their density is about roughly a quarter of that of water.

But now what about the break up of the younger matter, which ought to follow the programme of Laplace and Roche? Can we anywhere find visual proof of the reality of this other method of break-up? Can we, in other words, find in the sky any evidence of rotating masses of gas or other cosmical matter, these being of low density, of lenticular shape, and throwing off matter from their equators as they rotate? In the opinion of the writer, the sky is full of just such masses; they are the spiral nebulae.

By many the spiral nebulae are thought of as a pair of arms without a body, but for the moment we must fix our attention on the body of nucleus which is invariably present. Is it lenticular in shape? Does it rotate about its axis of symmetry? Does it throw off matter from its periphery? To each of these questions recent observations give an affirmative answer.

Are the nuclei lenticular in shape? The shape can of course only be studied by catching in the telescope nebulae which are seen almost or quite edgewise-on. Of such nebulae the best-known in the nebula in Coma Berenices (H. v. 24), and the nucleus, although not very clearly defined, is readily seen to be lenticular in shape. Five more satisfactory nebulae appear edgewise-on in the recent fine collection of photographs published by Pease from Mount Wilson.—Their N. G. C. numbers are 3115, 4216, 4594, 5746, 5866, and in each case the nucleus is seen, with more or less clearness, to be lenticular in shape.

Do these nebulae rotate about their axes of symmetry? Nothing was known as to the rotation of nebulae before 1914, in which year Slipher announced the rotation of the nebula in Virgo, N. G. C. 4594 already mentioned. Since then other nebulae have been found to be in rotation, always about their axes of symmetry. The spectroscopic discovery of rotation is an operation of very extreme delicacy and difficulty, all the more so as the spiral nebulae give mainly continuous spectra. For this reason the number of known cases of nebular rotation is small, but there is no reason to doubt that it is a general law that the nuclei of nebulae are in rotation about their axes of symmetry. Two of the best-known nebulae in the sky, the "whirlpool" in Canes Venatici (M. 51) and the nebula M. 101 in Ursa Major have been found to be in rotation by the direct method of comparing photographs taken several years apart.

Do these nebulae throw off matter from their peripheries? A moment's reflection will show how difficult it must necessarily be to test this directly. That the motion in the spiral arms is from inside to outside is a *priori* very probable on account of their extreme symmetry. Those cosmogonists who see in the spiral arms streams of stars dashing inwards to collision with one another can never have stopped to reflect how utterly improbable it is statistically that their streams of stars, encountering one another at random, should invariably be so similar in mass, density and velocity of motion as to produce always symmetrical formation. The almost complete symmetry of the spiral arms is probably the best proof we can ask for that the motion is from inside to outside. For the two nebulae M. 51 and M. 101 whose motion of rotation has been discovered by direct photography, it is of course possible to examine the direction of motion in the arms directly. In each case it is found to be outwards. Slipher has just announced that there is evidence of similar motion in the nebula in Cetus N. G. C. 1068. Thus there is every justification for interpreting the spiral arms as matter thrown off from the rotating nuclei.

Laplace, followed also by Roche, expected the ejected matter to form a ring. We have found reason to think that in point of fact it forms in nature two spiral arms. Laplace, however, did not consider what it would form in nature; he dealt with the mathematical abstraction of a mass of gas rotating in a universe empty except for itself. The real astronomical mass of gas rotates in a universe tenanted by other masses of gas similar to itself. In Laplace's abstract problem all points on the periphery of the mass necessarily fared alike—there was, indeed, nothing to distinguish one from another. But under actual conditions two points on the periphery will differ in their nearness to, or distance from, other neighboring masses. The lenticular figure, when once its sharp periphery is formed, is already in a critical state of equilibrium; centrifugal force around this periphery is just up to the maximum amount which the gravitational attraction of the mass can balance: only one straw more is required to break the camel's back. And this last straw may be provided in nature by the tidal forces, no matter how feeble these may be, from the rest of the universe. At two opposite points on the periphery these tidal forces will act so as exactly to reinforce centrifugal force against the attraction of the mass. At these two points earlier than at any others the balance will be upset; centrifugal force will outweigh gravity, and the break up of the mass will begin. Thus matter will be ejected, not in rings, but in filaments which will occur in pairs originating from antipodal points on the periphery. In all known spiral nebulae the arms start from two antipodal points.

In all known nebulae the arms are entirely or approximately symmetrical. On the foregoing view of the formation of the arms this fact finds a ready and natural explanation, the tidal forces from neighboring masses being sufficiently represented mathematically by a second harmonic term which produces a fore-and-aft symmetry of the type we are familiar with in terrestrial tides. No other view of the genesis of the spiral arms seems to me to give a natural, or even a defensible, explanation of the symmetry of the two arms.

No explanation of the arms can be regarded as fully satisfactory which does not explain their characteristic shape. This has been shown by van Pahlen to be an equiangular spiral. I have found that under very high viscosity the streamlines of the ejected matter would form equiangular spirals, but it has to be admitted that the degree of viscosity required appears to be greater than can be accounted for in terms of known physical factors. However we possibly are not familiar with all the physical factors at work in matter of such low density as the nebulae. The equiangular spiral is a curve which seems to occur very naturally in connection with matter ejected under centrifugal force—for instance, a system of beads running freely on the spokes of a bicycle wheel will describe equiangular spirals in space when the wheel is rotated with uniform velocity. The angle of such spirals is uniformly 45°, so that this principle, without modification, is not sufficient to explain fully the spiral paths of ejected nebular matter.

Laplace imagined that his ring would in time become unstable and break up into planets. Will our filaments of ejected matter become similarly unstable? Plainly the question is one for the mathematician to answer. The answer given is that the filaments will become unstable much in the way imagined by Laplace if they are on a sufficiently massive scale, but not otherwise. A filament in which the mass per unit length is small will simply diffuse away into space; its mass does not provide sufficient gravitational attraction for it to cohere together. Such a filament would not admit of astronomical observation at all. But a sufficiently substantial filament, it can be shown, will become unstable through nuclei forming at approximately regular intervals, and the remaining matter will ultimately condense round these nuclei and form a chain of detached masses. It is accordingly significant that such nuclei appear in the arms of most spiral nebulae.

The mathematician can calculate the distance apart of the nuclei which will be formed in any given filament, and so can deduce the amount of matter which will appear in each of the final detached masses. The calculation is interesting; assume a reasonable value for the density of the primitive nebula and it appears that the separate bodies will be comparable in mass, not with our planets or satellites, but with the sun itself. If, following Laplace, we identify the primeval nebula with our sun spread out to include the orbit of Neptune, then it seems highly improbable that planets of the size of Mercury and Venus could have been formed from condensations in such a nebula, and quite impossible that the asteroids and smaller satellites could have been so formed. Indeed, nebulae of mass as small as our sun could throw off matter equatorially as imagined by Laplace, but this matter could hardly have condensed into arms at all. It is conjecturable that the "planetary" nebulae may be masses of this kind, but it is fairly certain that the spiral nebulae, at least as regards those which show condensations in their arms, cannot be. Thus the process imagined by Laplace operates on a more majestic scale than he conceived; the masses in question are the giant masses of the spiral nebulae, and the final products of disintegration are not systems of planets and satellites but streams of stars.

To illustrate this we may consider the special case of the Ursa Major nebula M. 101. Van Maanen finds the period of rotation to be of the order of 85,000 years, whence it can be calculated that the density of the nucleus will be of the order of 4×10^{-17}. The density in the arms will be less, perhaps 10^{-17}, in which case condensations would form at distances of about 10^{12} kms. apart. The actual condensations in the arms of this nebula, unfortunately rather indistinct, may be estimated perhaps as being at an average distance of 5" apart. If so, we have a measuring rod with which to explore the nebula: $5'' = 10^{12}$ km. The distance of the nebula we at once find to be about 1,500 parsecs or 5,000 light-years; the mass is of the order of 10^{37} grammes, say equal to 5,000 suns. This mass, then, is under the influence of increasing rotation, breaking up into stream of stars. Each star is of mass comparable with our sun, and the stars are generated at the rate of one every few hundred years.

This illustration will have disclosed the scale of the picture which is opened up to us by following up the ideas of Laplace. In such nebulae as the Andromeda Nebula or the Ursa Major nebula M. 81 we may almost imagine that the whole picture is spread before us. In the center of the picture, the rotating nucleus whose continual shrinkage has set the whole machinery into operation; at the boundary of this, the critical region at which centrifugal force and gravity are so evenly balanced that the slightest influence from outside may upset this balance; at two opposite points on this boundary, the regions at which the balance is upset, conjecturally by tidal forces from other masses. From these two points, two streams of matter emerge: they are diffuse and gaseous at first, but gradually we see the condensations or nuclei appearing, and the final creation of streams of stars is not difficult to imagine. We can in imagination look at the same picture some millions of years later. The stars have condensed about their nuclei and formed separate masses; we have no longer a nebula but a star-cluster. Some of the flatness of the original nebula may still remain but the cluster has approached towards a more globular form. The regularity of the motion of the streams of stars which originally formed the spiral arms will not have been obliterated entirely, so that the phenomenon of "star-streaming" may perhaps still be discernible. The individual stars will have shrunk to densities far greater than they had when they were first formed; with this shrinkage their rotation will have increased, in many cases binary and triple systems may have been formed.

It must be admitted that a good deal of this is conjectural, perhaps visionary. But it must also be admitted that Laplace's fundamental ideas, when developed mathematically to their logical conclusions, show a striking capacity for interpreting many if not most of the formations observed in the sky. Perhaps it is vague clues rather than full explanations that have been yielded so far; the time for full explanations has not yet come, but the outlook is full of hope. The only formation which Laplace's hypothesis now seems definitely unable to explain is, paradoxically enough, just that particular one which it was specially created to explain, namely, the solar system. Laplace's intuition and his mathematical ideas were wonderfully accurate, but he was led into a faulty application of them. A final verdict cannot yet be pronounced—any attempt to do so would be dogmatism—but it may be that before long the reasoned and considered verdict of astronomers will be that the hypothesis is at the same time a failure and a splendid success—a failure as regards the immediate purpose for which it was was designed; splendid in having achieved a success greater than any that its author could possibly have dreamed of.

Cambridge, Trinity College.

"Benzoil Oil" (Benzine Oil): A New Fuel for Motor Vehicles

This fuel is a mixture of equal parts of benzol and Diesel-engine oil. Its practicability has been tested by the Road Vehicle Testing Commission, Berlin. The material will be used as a substitute for petrol and benzol until further notice. It is of yellow to reddish-brown color, has a specific gravity of 0.84 to 0.895, and evaporates between 68 and 200°C.

In view of these properties, which characterize benzol oil as a fuel difficult of vaporization, some care is required when using it for road vehicle propulsion. The delivery of the mixture must be carefully regulated so that sufficient air is given and a preheating device of some kind is evidently necessary. Starting up is effected by injecting petrol or benzol into the cylinder, although the engine will generally start on benzol oil.—Abstrated by *Technical Review* from *Zeitschrift des Vereines deutscher Ingenieure.*

Copying Fingerprints—II

The Durability of Fingerprints on Glass; and the Use of Heat for Revealing Imprints on Paper

By Robert de Résillac-Rosé

[Concluded from Our Issue of Sept. 13, 1919, No. 2280, Page 173-174]

DURATIONS OF IMPRESSIONS EXPOSED TO WEATHER.

In order to ascertain the length of visibility of latent fingerprints on glass, windows, etc., when exposed to atmospheric conditions, I had a number of glass plates covered with finger impressions—three on each plate—placed them in a horizontal position on the roof of my house and exposed them to the weather for more than two months.

These impressions on the glass plates were made on March 6; during the remainder of this month we had more or less rain on eight days. The two following months I noted a great variety of atmospheric conditions:

In April, from 7th-10th:	frequent showers.
" " 16th (night):	2 inches of snow.
" " from 9th-24th:	intermittent showers.
" " 25th:	thunderstorm with very heavy rain.
In May, from 5th-8th:	intermittent showers.
" " 11th:	severe thunderstorm.
" 14th-15th:	thunderstorm with heavy rain.

I examined a certain number of these plates every ten days or two weeks. Most of the impressions that I examined on March 21 were so well preserved and so distinct that their photographic reproduction would have shown clearly every ridge pattern. On March 31 I ascertained that those impressions which were first made on the plates, were all very distinct, while the second and third ones were not so well preserved. The reason for this is undoubtedly the fact that the first finger impressions contained the greatest quantity of fatty or oily excretion, the second and third ones less, because the finger with which each of these imprints was made had not touched the face, hair or skin during the first, second and third impression and had not come in contact again with the excretion of the skin.

This fact was still more evident on April 25; only those plates which had been touched by a finger containing a strong fatty excretion showed well preserved ridges; all other impressions were smudgy and indistinct. On May 17 only 2 fingerprints were well preserved.

From these observations the conclusion must be drawn that the preservation and visibility of a fingerprint on glass depends on the quantity of oily excretion which the finger transmits on the glass; the greater the quantity of fatty substance on the finger, the longer the fingerprint will be preserved; the less fatty substance the fingerprint contains, the easier it will disappear.

As mentioned previously, these experiments were made on glass plates that had been placed in a horizontal position on the roof of the building. As objections to these experiments might be made for not being "natural," because windows are exposed to the influence of the sun, rain, snow, wind, etc., vertically but not horizontally, I had fifty impressions made on the outside of a window of my house, facing east.

I had these impressions made on the same day as the others, *i. e.*, March 6. On May 13, after more than two months, I observed that 17 of the 50 fingerprints were still so well preserved that their different ridge patterns could be easily recognized. I noticed that the best preserved impressions were nearly all on the upper part of the window; the lower ones had been nearly all washed away by the flowing together of rain drops.

In order to determine whether fingerprints on glass are differently affected by the various temperatures, atmospheric conditions of the different seasons, etc., I made further experiments. On June 2 I exposed 25 glass plates, each with 3 impressions, on the roof of the building to the weather. On June 2, 3 and 4 we had thunderstorms; when I examined the plates on June 6 I observed that six of the impressions were barely noticeable. On June 7 and 8 we had thunderstorms again; the following days were very sultry and hot; on June 9 I found impressions on only two plates, and on June 16 every fingerprint had disappeared.

From these experiments it becomes obvious that the atmospheric condition of the different seasons is a strong factor in the preservation of fingerprints. Heavy rains, intensive sun radiation, heat, great humidity, etc., destroy fingerprints quicker than the cool and overcast weather during the winter and spring months.

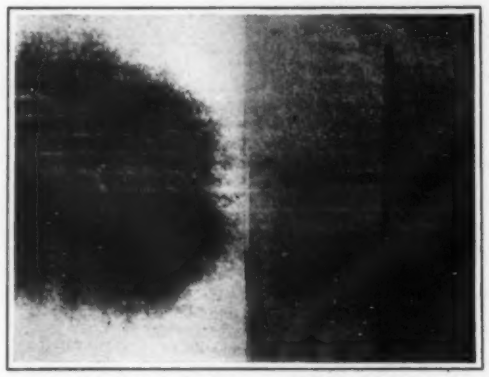

Fig. 1—Fatty marks which have spread under heat development.

Fig. 2—Marks due to Sodium Chloride heat development

All these experiments prove conclusively that the preservation of latent impressions depends on: (1) How much oily excretion has been deposited on the touched glassy surface; (2) that at the examination of windows for finger impressions the chances are by far greater to find them on the upper part of the window than on the lower one; (3) that even continuous rains will not efface impressions and that such impressions may be found even after the lapse of several months when they may be revealed by the powdering process and photography or by "lifting," and thus make it possible to identify and convict criminals who have left their fingerprints unintentionally on glass, windows, etc.

DURATION UNDER INDOOR CONDITIONS

I also erperimented with fingerprints on glass, silverware, etc., in a room, to satisfy myself how long impressions under these conditions will last and whether powder will adhere to these impressions sufficiently to permit a positive identification. Though I found the impressions after three months somewhat dusty, those made during the first week were just as clear as those made during the last week of the three months, and every single fingerprint showed a very distinct pattern picture after it had been sprinkled with powder.

METHODS FOR REVEALING IMPRINTS ON ROUGH SURFACES, OR IMPRINTS OF CONSIDERABLE AGE.

Latent fingerprints on solid, smooth objects such as polished wood, metal, glass, etc., are made visible by the powdering process with various color-powders used for this purpose. This method, however, can be then used only for making latent fingerprints on paper visible when the paper is smooth, when the impression is of recent date and is capable of absorbing the color-powder. As such impressions are in most cases not of recent origin, the powdering process will prove rather unsatisfactory. If the paper has a rough surface, nearly as much of the color-powder will adhere to the paper itself as to the impression that is to be made visible; in these cases, and when we have to deal with valuable documents that have to be handled very carefully, we have to resort to the fumigation process with iodine vapors. When an impression on paper is very old and all other methods fail, the fingerprint must be etched with hydro-fluoric acid.

But the fumigation process with iodine vapors, which so far has been employed in such cases, has the following disadvantages: (1) the fingerprint which is made visible by this process disappears after some time owing to the great volatility of the iodine; (2) the paper around and between the ridges shows strongly yellow colored, so that sharp contrasts do not result. Both these circumstances are to a certain degree detrimental to the photographing of such impressions; a good photography with distinct ridge patterns is absolutely necessary for the identification of such impressions. The very important fact must also be mentioned here that an impression made visible by iodine vapors and that disappears after some time owing to the great volatility of the iodine, "can never be made visible again."

Notwithstanding its many advantages, the following method, *i. e.*, "the utility of heat for making visible latent fingerprints on paper," has so far never been used in this country. A number of most interesting experiments with heat as a developer of latent impressions on paper were made at the Criminalistic Institute of the University of Graz, Austria, which are published here for the first time:

When the finger with its fine porous openings in the ridge lines touches an object the transpiration of the skin takes place through these pores and a mixture of water, sodium chloride (common salt), urinary salts, fatty acid and other substances are excreted. When this mixture is heated, the organic substances carbonize without the occurrence of sufficient oxydation, because these organic substances are surrounded airtight by the urinary salts; for this reason we notice the brown coloring which results from the heat, and not from the carbonizing of the fatty substances as was until recently erroneously believed. The following simple experiments will prove this error:

Figure 1 represents a piece of paper, on which fatty marks were made at certain places, and was exposed to heat. The result shows that the fat at a certain temperature distributed itself nearly across the whole paper surface and that only an indistinct brown color was noticeable at those places where the fatty marks were made.

Figure 2 shows an entirely different result. In this case the paper had been brushed over with a solution of sodium chloride, and it was then heated, whereupon stripes of a grayish-brown color appeared. The proof was thereby furnished that carbonized fats could not have been the cause of this coloring: neither was it the salt that became brown, as salt does not change its color even at a very high temperature, but it was the particles of the paper that were loosened and torn away from the paper surface when it was brushed over with the solution and certain organic atoms in the salt itself that carbonized through the heating process.

The excretion process through the pores is uninterrupted; if we touch with our fingers a piece of paper or press the whole hand on it, the excretion is transferred to the paper by the contact of the skin with the paper. As the pores are lying side by side in the ridge lines, the latter will be always more or less moist and act through the close contact with the paper like an engraved plate with the difference that the transpiration of the skin takes the place of printer's ink. If such a prepared paper is exposed to the heat, the ridges of the fingerprint will appear in a very short time yellow; at continuous heating they can be strengthened to a strong brown color. The paper itself, of course, will be colored by its partial carbonization, which for this reason seems to have the same disadvantages as when the paper is fumigated with iodine vapors, but the obtained contrasts are much more pronounced and the fingerprints will gradually appear in a strong, brown color. It is necessary to use a rather high temperature, *i. e.*, approximately 400-650 deg. F.

This heating may be done by means of a candle, gas, alcoholic lamp, or whatever source of heat may be handy. As through the close contact of the paper with the hot flame the former is liable to ignite or to become blackened, it is advisable to place the paper between two layers of isinglass, held firmly together at the sides with two metallic paper fasteners. The side of the paper with the fingerprints is exposed to the heat; the protected paper is heated carefully and evenly by moving it over the flame in all directions with a moderately quick action. It will be necessary to examine from time to time the progress of the development in order to interrupt the heating at the proper moment. The heating is discontinued as soon as the ridges appear in a strong brown color, which are suitable for practical comparison with the impressions of the suspected individual.

This method, however, has the disadvantage that the isinglass plate nearest to the light will more or less expand at the place where it has been heated the most and will buckle, whereby an uneven heating of the paper and the formation of spots results. For these reasons it is best to make use of an ordinary

kerosene lamp with a very narrow chimney, instead of an "open" flame. As the paper here is only exposed to hot air, there is no need of isinglass protecting plates. The side with the fingerprints is held over the chimney, let us say, at a distance of two to three inches, and is moved carefully back and forth in a horizontal position. The paper becomes transparent through the action of the light and the pattern ridge lines become clearly and distinctly visible. As soon as the impression shows its outlines they can be strengthened by holding the paper at that place for a short time over the chimney. Then we search for other imprints on the paper. If, for instance, the impression of a whole finger is discovered, the paper is moved back and forth at that place. The fingerprint will be noticed in a distinct brown color, while the rest of the paper will not be colored.

When impressions on paper are made visible by iodine vapors, the paper has to be placed in a suitable air-tight glass vessel on whose bottom we deposit a few iodine crystals. Iodine evaporates at the average room temperature, and the fingerprints are made visible by its vapors. It is not advisable to use a higher temperature than that of the room temperature, for instance, by heating the vessel. In case this is done, the iodine, owing to its great specific weight, will color the nearer exposed parts of the paper very strong yellow, while the other parts remain untouched. The crystals must not be placed too close to the paper, otherwise the iodine will act too strongly.

As soon as the impression has been made visible in this manner, we place tracing paper over the developed impression and trace its pattern with a pencil on the tracing paper. In this manner a sketch of the pattern is obtained, by which after the evaporation of the iodine and the disappearance of the fingerprint, it is possible to fix the exact location of the fingerprint on the paper. Such obtained impressions can then be permanently made visible by the different described heating processes. Care must be taken not to expose the paper too long to the iodine vapors, because the ridges will not show then in strong contrast.

If the impression appears indistinct, it is powdered with colored lycopodium. If this powder adheres to the impression and the pattern shows clearly, the heating process under the mentioned precautions is then applied. The impression is brushed off with a fine brush after the heating.

Still better results are obtained by using fine asphaltum powder, which melts at a very low temperature and whose individual powder particles unite at the melting and form in this manner uniform lines. The "browning" of the organic substances and the color of the asphaltum will produce a very distinct ridge picture.

To illustrate the effects of the salts, which are contained in the human excretion, for obtaining distinct finger impression patterns, the following experiments will be of interest:

We prepare a 20% solution of sodium chloride (common salt), pour two drops on the hand, rub them evenly over the inner surface of the hand, and after they have nearly evaporated we press the hand on smooth, clean paper. When the paper is heated at that place over a lamp chimney, we obtain a beautiful distinct ridge picture. (Fig. 3.)

Very distinct ridge pictures are obtained when we increase, besides the salt quantity, that of the carbonaceous substances, for instance, with a mixture of salt-and-sugar solution. Specially good results are obtained with a mixture of 6 parts of water, 1½ parts of salt, 1 part of sugar, 1 part of hyposulfide of sodium, and ½ part of mucilage.

It is hardly necessary to call attention to the fact that in each one of the described methods the experimenter should use either pincers or should wear gloves, as otherwise an impression of his own finger would result whose existence would be extremely annoying and disastrous to the experiments.

Fig. 3—Illustrating the distinct ridge picture obtained by effect of the salts contained in the skin secretions. Imprint in 20% salt solution after heating.

A Statistical Survey of Color Vision

It is well known that many people with slightly abnormal color-vision exist, and this suggests a statistical method of treating color-vision. If 1,000 persons could be examined, and marks awarded for color perception, and if, further, a curve were plotted relating the number of individuals in each class of proficiency to the number denoting the class, evidence on the validity of the Young-Helmholtz theory could be secured. If two maxima exist, a small maximum for the dichromats and a large maximum for the trichromats, this would support the theory; but if only one maximum was found it would appear that color blindness is not due to absence of one of three primary color-sensations.

The author, R. A. Houstoun, applied the method to 79 observers, of whom 38 were women. The method consisted in noting the number of separate colors discernible in the spectrum. The apparatus, which is a variant of that adopted by Edridge Green, is discussed in detail. The author can see 17 patches under favorable conditions, but acuteness in this respect depends to some extent on the intensity of illumination. The numbers recorded vary from 5 to 26. Two obviously color-blind subjects are included, and four observers with exceptionally acute color-vision could "see-indigo." The diagram prepared from these data has two well-defined and nearly equal maxima in close vicinity but also gaps at the ends of the series. However, it would require a much larger number of observations positively to disprove the existence of separate maxima for dichromats and monochromats.—*Science Abstracts.*

Pavement Temperatures

In England the effect of solar heat on paving materials is not of great importance, but in hotter climates the sun's heat has a very considerable effect on the choice of materials with which it is possible to surface roads and footways, and in this connection some investigations carried out in Chicago, and described in the *Engineering News Record* by Mr. G. S. Eaton, are decidedly instructive. Another direction in which paving materials will be more seriously considered in the future is the influence their temperature, when subjected to the sun's rays, has on the life of rubber tires. The investigations just mentioned were made during the height of summer, when the official maximum temperatures recorded were about 120° F. During the middle of the day the effect of the pavements in heating the air above them was noticeable, as thermometers 1 and 4 feet above the roadways read from 3½ to 4½ degrees higher than over a lawn in the sun. Over the asphalt the readings averaged 1 degree higher than above the concrete, and ½ degree higher than above the brick. After 7.30 p. m. the temperatures above the surfaces were practically the same as those of the surrounding air. The presence of large lawns and shade trees probably hastened the cooling and somewhat different results might be expected in the closely built-up sections of a city. Temperatures in the shade, 30 feet away, were not influenced by the pavements. Curves given by Mr. Eaton show that at the actual surface of the roadway a temperature of 123° was attained with an asphalt surface, while, in similar conditions, a brick road only reached 116° and concrete 110°. The temperature over grass was just over 102°. Another feature brought out by the curves is the much more rapid heating and cooling of brick roadways as compared with concrete.—From *The Engineer* (London).

Deep Etching of Steel

The following points from a report of an investigation carried out under the direction of the Rail Committee of the American Railway Engineering Association are of special interest:

The discovery of the value of deep etching with strong acid is bringing out hitherto unrecognized defects in the interior of the rail head. The Altoona Laboratory of the Pennsylvania Railroad has for some time suspected that chemical analyses of samples from different parts of the cross-section of the rail do not give sufficient information as to its quality. Further, the usual micrographic etching solutions employed have proved unsatisfactory, and definite results have been secured only when the specimens were etched for two hours in a mixture consisting of nine parts of hydrochloric acid, three parts sulphuric acid and one part water, kept at 200° F. This brought out a remarkable number of longitudinal, transverse and irregular marks or depressions, and these marks, representing streaks of more soluble materials, proved the existence of serious non-homogeneity, which hitherto could not be discovered otherwise.

In a rail that had never been in service the deep etching with strong mineral acid mixtures brought out indications of irregularity of structure, whereas picric acid etching has failed to develop anything unusual. In this connection an observation is reported by J. B. Young, chemist of the Philadelphia and Reading Railroad, whose tests indicate the likelihood that flaws and cracks may exist in new rails which have been subjected to no strains except those developed in the rolling.

The second point brought out by the research of the Rail Committee is that statistics prove that about all transverse fissures occur in rails rolled directly from the ingot, while rails from reheated blooms virtually never fail in this way. If true, this would prove that defects of the ingot rather than excessive stresses are responsible for transverse fissures. As an editorial in *Engineering News-Record* (March 27, 1919, p. 599) remarks, it may be deduced from these data that there seems to be more promise in metallurgical studies of rail steel and examination of furnace and mill conditions than in the study of track service.

Tests of rails by a magnetic tester to detect internal flaws were made by Dr. P. H. Dudley of the New York Central Lines. He gives no details as to results obtained, but states that the leakage curves of rails obtained with this apparatus furnish much information about the physical properties in rails and about the disturbance of the metal by the gag press.

For acceptance tests on the Pennsylvania Railroad rails are subjected to a press bending test in addition to the regular drop test. The press is in a hydraulic machine operated by an intensifier standing alongside, and capable of exerting a pressure of 378 tons. The main ram is 16 in. in diameter and has a 12-in. stroke. The machine weighs 11 tons. The support for the rail, under the pressure ram, may be set at various spacings; tests have been made with supports 24 in. to 51 in. apart.

Deflections at ultimate load of rail specimens bent in this machine are found to be an indication of the ductility of the material, just as well as is the elongation in the drop test of the rail. It is also believed that the deflection is in a measure an indication of the toughness or capacity to resist shock.

Tests made up with the head down (in tension) gave more satisfactory and uniform results than those made with the head up. In the former, breaks were obtained in nearly all cases, while with the head up the breaks were apt to be branching or irregular.

One of the striking results of tests with the bending machine brought out in a report on the subject submitted by W. C. Cushing, chairman of the subcommittee on the quick-bend tests, is the distinct superiority in quality of the rails produced by one mill as compared with those of another. A large number of tests of 130-lb. rails from three mills, plotted to show elastic limit as ordinates and ultimate deflection as abscissae, placed the rails from one of the three mills in a group distinctly above and to the right of the groups representing the other two mills. This comparison shows greater ductility and strength, on the average, for the rails of the first mill, though all were rolled to the same specification and the same section and weight.—*Mechanical Engineering.*

Prime Mover of High Efficiency–II*

The Still Engine which Combines the advantages of Steam with those of internal Combustion

By Frank E. D. Acland, M. Inst. C. E.

[Concluded from Our Issue of September 27, 1919, No. 2282, Page 205.]

Detailed figures of these trials would exceed the limit of these notes, but the following *résumé* of the results shows the effect of the interaction of the combustion and steam cycles.

1. The *mean* temperature of the cylinder walls is higher than in ordinary engines; the cooler parts being maintained at a higher, the hotter parts at a lower temperature.

2. The piston is cooler, owing to the expansion of the steam behind it.

3. The heat efficiency of the combustion cycle is augmented because the walls are at a higher and constant temperature, and is in proportion to the rise in temperature of the jacket water (*cf.* Hopkinson's trials, Daimler engine).

4. Frictional losses are reduced (*cf.* Hopkinson) by the higher temperature and because the steam overcomes the inertia of the reciprocating masses at the lower dead line.[1]

6. The steam, expanding as it does in a cylinder hotter than itself, gives an indicator diagram larger than that theoretically obtainable under ideal conditions in an ordinary steam engine.

7. Twenty-nine per cent of additional brake-horsepower is added to the shaft of the engine, without increase in the fuel consumption (steam not condensed).

8. Forty per cent is added with condenser used. (Air pump separately driven.)

9. The i.h.p. due to steam appears as b.h.p. added to the shaft, all the mechanical losses having already been accounted for in measuring the combustion b.h.p.

Normal Load.—The average m.e.p. from the combustion stroke was 90 lb. per square inch. The steam evaporated by the "waste heat" gave 14 lb. per square inch m.e.p. on every return stroke. This is equivalent to 90 + 28 = 118 lb. per square inch m.e.p. in a normal four-stroke engine.

Overload.—By admitting additional steam generated by fuel under the boiler, the steam m.e.p. was raised to 72 lb. per square inch; the total m.e.p. was, therefore, equal to 90 + 144 = 234 lb. per square inch. m.e.p. in a normal four-stroke engine.

GAS ENGINES.

The first experiment engine constructed was a two-stroke engine capable of developing 590 b.h.p. from three cylinders at 400 revolutions, bore 8 in. It was a high speed engine, designed with special regard to obtaining data about the recovery of steam from waste heat (jacket and exhaust). It was first operated on town gas—540 B.Th.U.s, and subsequently converted for oil fuel. Its efficiency was not high, owing to its being a two-stroke engine with a short stroke, but its consumption per b.h.p. was 15 cubic feet per hour (31.3 per cent efficiency), a very promising result.

The outbreak of war prevented much progress being made in the design and construction of gas engines; but the results achieved give great promise of future development, for with a combustion indicated efficiency of 36 per cent, radiation 4 per cent, boiler loss 10 per cent, there remains 50 per cent for recovery: allowing 10 per cent efficiency for the steam cycle, a gain of 5 per cent is assured, and the total indicated efficiency of the engine will not be less than 41 per cent. If 20 per cent efficiency is obtained from the steam cycle, as appears possible, the total indicated efficiency will be 46 per cent.

A gas engine which can give a brake thermal efficiency 30 per cent better than its predecessors, and which, by governor control alone can meet any demand up to and over 100 per cent overload, while maintaining a good efficiency at that increased output, cannot be neglected.

In November 1916, at a meeting of the Royal Society of Arts, Sir Dugal Clerk, F.R.S., read a valuable paper in which he alluded to the important part taken by Britain in the origin and development of steam motive power as being acknowledged as supreme; and he emphasized the leading part, not perhaps adequately recognized, which this country can claim in that great field of invention covered by internal-combustion engines, in which he himself has been, not only a leading contributor, but one to whose work and writings all students of the art and engineers are under deep obligations. In mentioning the attention devoted by German designers to gas and oil engines of large cylinder dimensions, he contrasts the attitude of English engineers by stating that "from the scientific point of view, they consider that the building of large engines, practically without modification of either thermodynamic or operative cycle, is a costly mistake, leading to a development in the wrong direction," and that "other methods must be found of increasing power in internal-combustion engines than mere increase of cylinders and massive construction of engine parts as practiced in Germany."

It is true that this country cannot yet claim great installations capable of 80,000 h.p., such as exist at Gary, Indiana, and where they have, with constant reliability and fine efficiency, proved their usefulness; but here, at this crisis, no possible source of cheaper power can be neglected. It is disappointing to read, in the report of the Fuel Research Board formed by the Privy Council Committee for Scientific and Industrial Research, that the gas engine, with its great possibilities and undoubted potentiality for improvement, both thermodynamically and in its operative cycle, is not alluded to; and the only source of power suggested for the countless millions of cubic feet of gas which are now still running to waste, and whose volume will be enormously increased when our coal supplies are more reasonably used, is by burning it under boilers for raising steam.

The thermodynamic cycles and the improved cylinder construction submitted to you, enable more powerful installations to be designed, and promise a substantial increase to their efficiency.

Great improvements have lately been made in gas producers, some of light weight, which answer automatically to all varieties of load. The addition of a steam cycle to gas engines operating with these producers, will give a means of manoeuvering and starting which will fit them for service as marine engines and locomotives for road or rail.

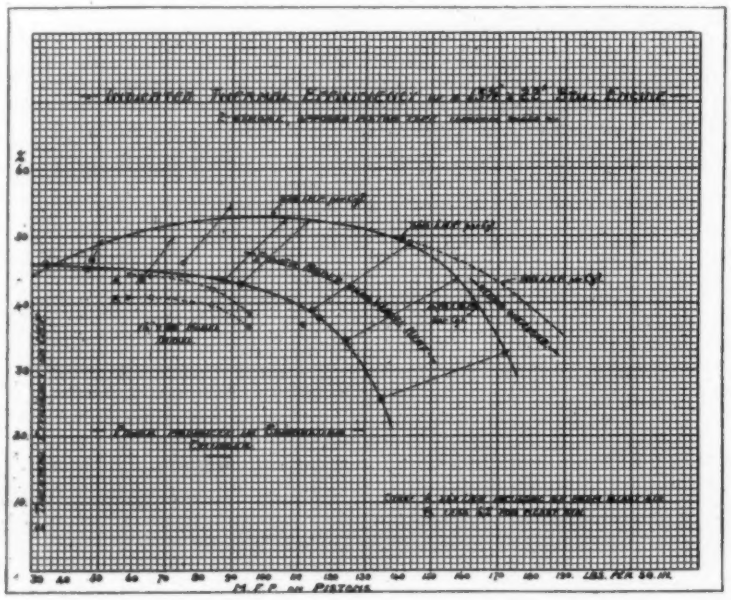

Fig. 5.

PETROL (GASOLINE) ENGINES.

Four-stroke engines for petrol (gasoline) and similar fuels have been built and tested ashore and afloat.

The diagram on the screen gives an example of a typical test of a single cylinder engine used for research work. It was fitted with a condenser, and maintained an average vacuum of over 25 in. As the temperature of the whole engine rose to its constant level, the m.e.p. per stroke given by the steam derived only from the "waste heat" gradually rose from 12 lb. to 14.5 lb. per square inch; the fuel consumption (petrol) averaged .42 lb. over the last four hours; but short period tests under best conditions showed consumptions as low as .38 lb., with a brake thermal efficiency of 36 per cent (condenser pump losses not included).

A three cylinder set (marine type) capable of developing, on its three small cylinders at 600 revolutions per minute, 12.5 shaft horse-power at 90 lb. combustion m.e.p., without power from the steam stroke, gave on continuous running, 16½ s.h.p. under "waste heat" conditions, maintaining from the "waste heat" a steady boiler pressure of 100 lb., without sufficient reserve for manoeuvring in narrow waters or bringing up. It would pick up very rapidly when ignition recommenced, and bring up the boiler pressure to normal in a few minutes.

With the addition of a burner below the boiler, it would run continuously and develop 38 s.h.p. at 750 revolutions. Momentary overload in proportion to the capacity of the boiler reached 60 i.h.p. (51.5 shaft). Under steam alone the engine is a most satisfactory performer—but not economical.

OIL ENGINES

Before describing the use of heavy oils in a Still engine, the two systems now in general use in the so-called semi-Diesel and Diesel engines may be referred to.

The semi-Diesel has been defined as "an internal-cobustion engine which has an uncooled portion of the combustion chamber serving to augment the heat generated by the compression pressure, and to assist in the vaporization and ignition of the fuel injected at the ignition point of the cycle." The fuel is usually injected directly, without air blast, into the cylinder. The majority of them are of two-stroke cycle. The compressure pressure is about 185 lb. per square inch. The fuel is injected before the compression stroke is completed, and brings about a rise in pressure and temperature before the expansion stroke commences. Later development of this type of engine appears to be bringing it nearer to the principles of Dr. Diesel by augmenting the compression pressure to about 300 lb., and so relying more largely on the increased temperature of the compressed air charge and diminishing or even eliminating the specially hot portions or bulbs in the combustion space. This results in a notable increase in the thermal efficiency, and the ability to start up from cold by the primary use of more volatile fuel without the application of external heat. It seems recognized that semi-Diesel engines are gradually approaching the Diesel principle, while the tendency in Diesel practice is towards reducing its initial pressures, and thus approaching that of the semi-Diesel.

The Diesel engine relies for ignition solely on the temperature reached by compression of its air charge. On starting, this is carried out in a cold cylinder with a direct loss of heat to the walls during the whole of the compression stroke. A compression pressure of 500 lb. per square inch is necessitated to overcome this heat loss. This high pressure increases the cost of construction and upkeep, and, since the maximum explosion pressure capable of being reached in a closed vessel may reach six times the pressure contained in it, the whole design and weight of the engine is detrimentally affected; but its brake thermal efficiency of 30 per cent to 32 per cent, coupled with twenty years

*Read before the Royal Society of Arts, May 26, 1919.

[1] In Professor Hopkinson's trials the frictional loss at 65° F. was nearly double that when the jacket water was at the maximum obtainable, 212°F. In Still's trials, the jacket water was at a constant temperature of 320°F.

of intensive development in all lands, has placed it at the head of all combustion engines in commercial operation which use heavy oils as fuel.

The Still oil engine starts with the cylinders and pistons pre-heated. The air charge, from the moment of its entry into the cylinder, picks up heat from the containing walls and continues to do so during at least 70 per cent of the compression stroke, with the result that the temperature necessary for firing with certainty the first injected charge of fuel is reached with a compression pressure 50 per cent less than that required in a Diesel engine.

This fact is far reaching in its importance, for it gives to the designer great elasticity and freedom of application; for a Still heavy oil engine can be designed for constant pressure or constant volume, or both can be employed in the same engine by correct timing of the fuel injection. It claims for its combustion cycle an efficiency higher than that of the Diesel, less weight and space per horse-power, and for its combined cycle an efficiency not less than 20 per cent higher than any primer mover which uses fuel as its source of heat.

The first engine designed for the use of heavy oil was of the opposed piston type, 16 in. diameter, 32 in. total stroke, revolutions 150, the combustion taking place between the two pistons with the steam generated by the jacket water and exhaust gases expanded at the back of both pistons (the steam passed from the auxiliary boiler through h.p. and i.p. cylinders and finally to the Still engine as an l.p. cylinder), and thence to the condenser.

The steam h.p. and i.p. cylinder was connected to a prolongation of the main shaft at 90 degrees to the main crank; all auxiliaries were separately driven, thermo-couples were connected to all important points in the plant between the combustion space and base of stack. The oil was injected by blast air, scavenged by a fan, pressures from .5 to 1 lb. per square inch. It was fitted with a brake and fly-wheel of 4¼ tons weight; from full power (300 b.h.p. at 160 revolutions) it will reverse by a single lever from ahead to astern in ten to twelve seconds.

The fact that these engines are capable of running under steam alone, and under constant temperature conditions, gives a facility and security in carrying out preliminary tests and subsequent accurate research which is not possessed by any other combustion engine. All mechanical adjustments, valve setting, degree of compression, temperatures, and so on, can be established at all speeds before any fuel is injected into the main cylinder. This was fully demonstrated in the design and testing of a special engine subsequently constructed to meet special conditions—where the maximum power in minimum space was the main desiratum—conditions not ideal for the highest efficiency.

The dimentions of the cylinder were:—Bore, 13½ in.; stroke, 22 in.; two-stroke cycle, opposed pistons; steam side as for l.p. cylinder. It forms the basis of a six-cylinder set, two of them using h.p. steam, which is compounded into the other four as l.p.

The combustion takes place between the pistons, the steam acting on the return stroke at the back of both pistons. After a series of preliminary tests under steam alone, in which data were obtained for the various mechanical adjustments, the scavenge, compression pressures and temperatures, at various speeds, oil was injected for the first time. The engine fired its first charge without hesitation, and completed a series of tests of over two hours' continuous running, without adjustment, giving an output by gradually increasing the weight of oil admitted of 100, 150, 200, etc., up to 400 i.h.p., at a maximum speed of 380 revolutions per minute, for which she was designed. The governing of this engine is best demonstrated by the diagram on the screen, which gives a set of cards ranging from 23.5 lb. per square inch to 141 lb. per square inch m.e.p., produced by the combustion cycle alone. This series of cards can be obtained at a constant or varying speed, progressively, from maximum to minimum or *vice versa*, or from extreme to extreme without any interval.

This unit has been subjected to many long and varied tests by representatives of various Governments, as well as to constant research work under severe conditions. Its best consumption of fuel (Admiralty shale oil) has been as low as .302 per b.h.p. (scavenge pump not included), over a test of one hour's duration under normal waste heat conditions. It developed 330 b.h.p. for six hours at 360 revolutions per minute (a single cylinder) under waste heat conditions. It will develop 400 b.h.p. at 380 revolutions over short periods (Combustion m.e.p, 128.2 lb., steam m.e.p. 57.9 lb., total m.e.p. 186.6 lb.). The thermal brake efficiency from below quarter load to full power is maintained at approximately 40 per cent over the whole range.

With added steam from the boiler, 5,000 b.h.p. would be obtained from two six-cylinder sets, with a weight of about 70 tons, including all auxiliaries and water, and extreme overloads up to 6,000 b.h.p. could be obtained (Figs. 5 and 6).

The application of the Still system to commercial marine work is being developed in this country and abroad; the two-stroke single piston type, in powers of 100 h.p. per cylinder and 400 h.p. per cylinder, having been adopted.

Engines of this type at 120 revolutions per minute, with a cylinder 22 in. diameter by 36 in. stroke, giving 4,200 s.h.p. on two shafts, with all auxiliaries and water, would approximate 600 tons. A geared turbine plant in a similar ship would weigh 20 per cent more, and would consume approximately 2,000 tons more fuel for a double journey lasting 1,000 hours.

LOCOMOTIVES

The success already achieved in proving the principles to be correct, both in theory and practice, has led to a careful study, both here and abroad, into the application of this system to locomotive work. No high-powered locomotive engine, using heavy oil or gas in its cylinders, has been produced capable of economical haulage of heavy loads.

A locomotive is a machine for accelerating a mass, and maintaining that mass at a constant speed. In the present type the best efficiency is attained during

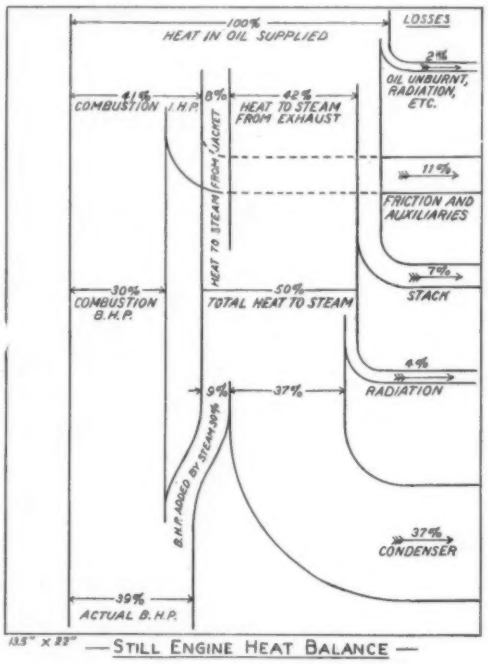

Fig. 6.

the short period of acceleration, say 10 per cent of its running time, and for 90 per cent it runs at an efficiency lower than any other steam engine, taking its place at the bottom of the list of heat engines, from a point of view of fuel efficiency. The overall thermal efficiencies may reach 5 per cent to 6 per cent: electrification, with steam generation might result in an efficiency of 8 per cent to 10 per cent.

A Still engine designed for locomotive work would be capable of giving an efficiency at the rails of 30 per cent over 90 per cent of its running time—in other words, six times as good as the present locomotive; while during the accelerating period its efficiency would be at least 15 per cent, or three times as good. In surmounting long inclines with heavy loads, the engine would be capable of developing about four times the power which it develops at its most efficient or normal running load.

It is surely not unreasonable to expect that the application of the system here described should be put, without delay, to practical test for locomotive work, and especially so in view of the development and enormous expenditure contemplated in the electrification of railways. To give up the unit system of traction where the failure of one unit does not involve the failure of the whole, and to rely on what is, after all, a delicate and easily dislocated source of energy from central power-stations, merely to gain a problematical 6 per cent increase of fuel efficiency, seems to involve a risk far greater than the encouragement and development of novel forms of engines, which, whether gas or oil, may be evolved at the present rate of progress before the country is too far committed to such a gigantic and possibly dangerous experiment.

Sufficient evidence has, it is hoped, now been given to show that, from the points of view of science and of practice, there is a great future before the combination of the steam and combustion cycles. From the theoretical side the possibilities of the combined cycle can be realized by the diagram on the screen, which shows the (*a*) ideal cycle at the high temperatures and pressures realizable by the combustion of fuel within the cylinder, and (*b*) that of the steam capable of being raised by the heat rejected in that operation—the one in accordance with the air standard of the Committee of the Institute of Civil Engineers, adapted to the combustion cycle (partly at constant volume and partly at constant pressure), as used in the Still heavy oil engine, and the other by the Rankine method. The two together give an ideal thermal efficiency of 67.8 per cent. That a two-stroke high speed engine of an early type, not designed specially for efficiency, should already have reached an actual indicated efficiency of 47 per cent, that is to say, an efficiency ratio of 70 per cent, warrants the assurance that still higher efficiencies will be obtained in later designs, where full advantage is taken of lessons already learned with regard to clearance, compounding, and so on, which are being embodied in designs now under construction.

But science and practice, like capital and labor, must work hand in hand. It is satisfactory, therefore, to state that in practice the Still engine can claim that it has carried out completely the objects of its inventor, and has corroborated and confirmed the principles on which he has worked.

These may be summarized as follows:

1. The higher mean temperature of the engine makes the combustion cycle more effective and more reliable in starting and in running.

2. The mechanical stresses due to heat are reduced.

3. The steam generated by the heat rejected by the combustion cycle augments the power of the engine without increasing the consumption of fuel.

4. The steam generated by the heat rejected by the combustion cycle cools the piston.

5. The steam generated by the heat rejected by the combustion cycle reduces the mechanical losses of the engine.

6. The steam generated by the heat rejected by the combustion cycle is used under exceptionally favorable conditions, since it absorbs heat during expansion.

7. The steam generated by the heat rejected by the combustion cycle suffers no condensation loss in the working cylinder.

8. The steam generated by the heat rejected by the combustion cycle warms the engine before starting, so that no sudden temperature changes occur in any part.

9. The steam generated by the heat rejected by the combustion cycle starts the engine against load if necessary.

10. The steam generated by the heat rejected by the combustion cycle enables manoeuvring at any speed from nothing to maximum and for any period.

11. Starting is unaffected by atmospheric conditions.

12. Power at normal loads is developed by combustion and steam from waste heat alone, with an efficiency at least 25 per cent above any known combustion engine of similar proportions.

13. Since the steam raised by the waste heat is more than enough to overcome the mechanical losses of the engine, the b.h.p. of the engine is at least equal to the i.h.p. produced by the combustion stroke.

14. Additional steam gives a large range of overload without serious loss in efficiency.

15. In engines using heavy oil as fuel, the compression pressures which ensure the ignition can be reduced by 50 per cent, as compared with the Diesel system.

The internal-combustion engine, during the present generation, has achieved an astounding success under conditions less favorable than those which are here presented; installations developing thousands of horsepower ashore and afloat, and beneath the sea, have been placed at the service of man. Fifty years of devoted science and practical skill have brought it to its present stage of serviceability. If the Still engine, in its infancy, has been able to show, in spite of the limitations of its upbringing, improvement in the thermal conditions, balance, torque, manoeuvring

(*Concluded on page 232*)

Vegetable "Plethora" *

Results of "Over-Feeding" of Plants and Differences in Habitat Between Individuals of the Same Species

By F. Gagnespain

CERTAIN singular phenomena exhibited by plants supplied with an excess of nutrition, have recently been described under the borrowed term of "plethora," though, perhaps, vital exuberance is a better phrase. When a plant, which contents itself ordinarily with a poor soil is transplanted into fertile soil it often develops a vigorous growth of leaves and branches, but without bearing seeds; it then may be said by an analogous use of the medical term to be in a plethoric condition. In the same way when a plant which lives in ordinary moist soil finds itself through some accident with its roots in the water, it may acquire a luxuriance of vegetation which indicates the same condition. This subject which is of great importance with respect to the raising of crops of various kinds has hitherto been but little studied. Certain interesting and curious facts relating to it and the conclusions which may be legitimately derived therefrom are set forth by M. F. Gagnepain in the April number of *Larousse Mensuel*, from which we quote.

The amphibious knot-grass (*Polygonum amphibium*) exists in two forms, one of which is terrestrial and has an upright position with leaves distributed along the entire length of the stalk; it also displays a more or less marked degree of pilosity, which is even exhibited at times by a marked glandulosity. The aquatic form of this plant presents a strikingly different aspect, having long submerged branches, which are leafless except for the crown of floating leaves at the end. This stalk terminates in a luxuriant spike of beautiful pink flowers. This aquatic form is capable of producing the terrestrial form when dried and inversely upon the bank of a stream some branches may assume the aspect of the terrestrial form, while other branches of the same individual may assume the floating form. This is the most beautiful example of stationary (stationnel) dimorhpism. But let us go a step further; if we examine under the microscope the anthers of the aquatic form we find that they are full of a watery pulp in which no organization is perceptible. I have had no opportunity of observing the pollen of the terrestrial form but there is no reason to think that it is not constituted quite normally. Thus we perceive that the expansion produced in the organs of vegetation by the milieu had destroyed one of the sexes; the male organ, the pollen, has become atrophied by reason of this plethora.

The water mint (*Mentha aquatica*) which always grows with its roots in the water, presents a similar case. When it is truly aquatic it is useless to seek for pollen in the anthers; but when a plant is found growing in better drained soil, the pollen is perfectly formed.

The monk's hood aconite (*Aconitum napellus*) prefers moist meadows. It is not rare in the Morvan. Its pollen is normal; but we have had the opportunity of observing a plant taken from the mountain side in this region and cultivated in a fertile garden at Autun, and only twelve per cent of the pollen was found to be well formed. The same thing may be observed in the raspberry (*Rubus Idaeus*); of two individuals, one of which is spontaneous while the other is cultivated in good earth at the same altitude, the former will have normal pollen while the later exhibits a large percentage of atrophied grains.

The examples just given and various others which might be added are peculiarly interesting with respect to the alteration or destruction of the fertility of the male element, when the individual plant vegetates in conditions of exuberance or plethora. These conditions almost always coincide with the development of stolons, or off-shoots, which reproduce the plant without the intervention of sex.

There still remain many observations and experiments to be made along this line. We might enquire, for example, why the common loose-strife (*Lysimachia vulgaris*) and the pond-weed found in marshes (*Stachys palustris*) exhibit pollen which is partially or totally infertile when their roots are completely immersed in water and why their stalk presents at its base floating stolons a meter or more in length. Or we may ask again why the (*Lysimachia mummularia*) which grows in rich, moist soil, almost never bears fruit, and why does the reed of our ponds (*Arundo phragmites*) which grows with its base in the water, never produce seed but bears instead numerous stolons at the base which send up young stalks from their nodes? And why is it that we can obtain fertile seeds if we cut these stolons entirely through?

The sugar cane (*Saccharum*) is cultivated for its precious juice and is usually grown in very rich soil; it always reproduces itself by means of layers and never bears seed, so that it can only be regenerated by means of seeds collected from plants grown in arid earth. Everyone knows, too, that the potato (*Solanum tubersum*) is propagated by means of tubercles, *i. e.*, without sex; but in certain races flowers appear, only a few of which, however, are succeeded by berries; the flowers themselves in fact are often abortive almost from the beginning. In our climate the white lily (*Lilium candidum*) bears fruit only in years which are exceptionally hot and dry, but it fruits normally in the climate of Naples. However, nowhere are the bulbs so well filled as in those cultivated near Paris. All the cases just cited exhibit an entire or partial loss of fertility and we regard ourselves as justified in thinking that this sterility is due to the vegetative exuberance of the individual plant. If the conditions of growth of these plants be changed seed crops can be obtained; numerous examples of this exist, the most curious of which, perhaps, is that mentioned by an old botanist, who gave the following advice for making the lily bear seed: "When the flower is in bud take it up with its bulb and hang it by a string in a barn; its flowers will expand and in due time seed will be formed." This experiment is worth repeating and we now possess an explanation of its surprising result. In our climate the lily soon sheds its flowers, allows its stalks to wither and concentrates its force in the bulb which is ready to produce leaves even by the end of the autumn. When we suppress the life of the bulb the vital power is concentrated in the stalk and in the ovaries. A rupture of equilibrium had previously occurred for the benefit of the vegetable life; when this is diminished the vigor of the plant is transferred to the sexual life so that fruits and seeds are born.

Since the cultivated garlic (*Allium sativum*) never produces flower or merely "cloves" at the top of the stalk it is possible that a similar treatment would cause it to bear flowers. It might be possible, too, to obtain seeds in this manner from the tarragon (*Artemisia dracunculus*) which bears seeds in its native country, China, as the garlic does in its native land of Siberia.

1. Amphibious polygonum or amphibious knot-grass exhibiting two terrestrial stalks and one floating stalk. 2. Water mint. 3. Much enlarged pollen of water mint. 4. Much enlarged pollen of monkshood (*Aconitum napellus*). 5. Much enlarged pollen of raspberry bush. 6. Common Loose-strife showing its long aquating stolons. 7. Numular or "money" Loose-strife. 8. Phragmite pond reed with subterranean stolon...9. Potato with abortive and caducious flowers.

It is evident that the object of every plant is to reproduce itself either by seeds or by spores. When certain plants, such as we have cited, find themselves, through natural or artificial accident, living in extraordinary conditions, they become plethoric and their fertility is more or less reduced: (1) either they produce no flowers and then there is a failure of the whole sexual system both male and female; (2) or they flower without bearing fruit and at least one of the sexes is atrophied. As we have seen in the examples mentioned above the pollen may be more or less abortive. Many cases exist, moreover, in which the ovary persists and even develops without having been fertilized. Such cases occur in seedless raisins, apples, pears and bananas. Moreover, when flowers become double this often occurs through the doubling of each petal and still more often by the transformation of stamens into petals; but the doubling does not affect the carpels, the female element.

It may be stated as a general thesis that vegetative exuberance is injurious to the sex life of the plant. It disturbs an equilibrium which always exists in the normal adult individual; the two elements of this equilibrium are the physiologic function which maintains the life of the individual organism and the sexual function which secures the birth of new individuals. The two systems ought to balance each other in the normal life—the sexual system consisting of the organs of procreation, flowers and fruit, and the vegetative system consisting of the organs of nutrition, roots and leaves. There are two ages in the life of the plant when this equilibrium does not exist—the youthful period before the development of the sexual system and the old age when the vegetative functions diminish in vigor. The state of plethora constitutes a more or less complete return to the condition of youth, a profusion of flowers on the other hand is ordinarily a sign of decrepitude. As soon as a healthy tree reaches the adult state it flowers and the two systems, vegetative and sexual, are in equilibrium. They maintain this condition of equilibrium until the arrival of old age or disease, provided the conditions of life are not disturbed. As we have seen, a state of plethora favors the vegetative system. We have witnessed experiments limiting the plethora and favoring the sexual system as described above. Let us now consider certain examples in which physiological poverty or under nutrition plays a part.

An apple tree grafted upon a wild tree never flowers although adult because it is too much rejuvenated by the pruning. A more intelligent gardener will employ a different process. He prunes either severely or scarcely at all, being careful to maintain the form

(*Continued on Page 232.*)

*Translated for SCIENTIFIC AMERICAN SUPPLEMENT from *LaRousse Menduel* (Paris).

Testing Rifle Ammunition

25,000,000 Shots Fired Annually by a Great Factory to Insure Standard Quality

IT is seldom that one realizes the extreme accuracy and care necessary in the manufacture of high grade ammunition for firearms.

The elaborate workmanship, processing and testing is usually hidden away in the factory, while the shooting public sees only the finished product, burnished and glistening—and appearing quite a simple thing to make.

In the manufacture of high-class ammunition, the services of the best ballistic engineers and most highly skilled workmen are necessary. Not only that but these men must have time, opportunity and money given them before they can develop perfect cartridges or shotgun shells. All of their work is hidden away and you cannot see it in the finished cartridge you hold between thumb and forefinger. It is not in evidence in the rows of boxes of ammunition on your dealer's shelves. But it is there. If it were not he could not afford to carry his stock.

It is reflected in that fine score you made yesterday. It shows in the accurate shooting, which would be impossible when using ammunition less carefully and correctly manufactured.

Let us take a trip through one of the big ammunition factories and see the extreme care taken to check up the quality of the ammunition being made.

Chronograph for Testing Velocity

THE TESTING DEPARTMENT.

Perhaps the most important department in cartridge making is the Testing Department. Here are hundreds of men engaged in testing the finished cartridges. No less than 25,000,000 test shots are fired every year by this company to insure their standard quality of output.

The remarkable record of this company is less than one sub-normal cartridge in every 6,000—less than one-sixtieth of one per cent. And yet with this remarkable record for highly efficient manufacture, the complicated and costly testing of cartridges constantly goes on. Every type of sporting cartridge down to the little 0.22 gets the same manufacturing attention and the same series of rigid inspections that is given the most important types of high velocity cartridges.

Let us look at some of these tests.

BANK TESTS.

Every hour men go through the plant and take samples at random of all kinds of ammunition from every loading machine in the factory. This ammunition is tested in all makes of guns to see that it functions properly in every gun for which it is designated.

This large arms company has over one thousand different makes of guns and revolvers and is constantly firing its ammunition in all of them in order to see that it always functions, smoothly and properly. This is called the "bank test," because the ammunition is fired into a large sandbank.

VELOCITY TEST.

The object of this test is to determine bullet velocity. The great accuracy required in making this test may be appreciated when one considers that measurements are made as fine as the one hundred thousandth of a second.

In making this test a fine wire is drawn across the muzzle of the gun and this wire is connected with an electrical attachment which holds a long rod. When the bullet leaves the gun's muzzle it breaks the wire and releases the rod. When the bullet reaches the target another connection is broken which releases a weight. This falling weight operates a lever which in turn makes a scratch on the falling rod. Thus we see that the distance between the zero mark on the rod and the point where the rod was scratched represents the distance the rod fell. Bodies fall at a definite rate and hence it is possible to translate this distance on the rod into time. The distance the rod fell is measured and converted into time by means of standard tables. We thus determine how long it takes the bullet to travel from the gun muzzle to the target, which is set at a given distance.

HANG-FIRE TEST.

Both shotgun shells and rifle cartridges are carefully tested for "hang-fire." By hang-fire is meant that the cartridge delays in exploding after the hammer strikes the primer. This delay may be as long as a half minute (30 sec.).

Two different kinds of tests are made to detect hang-fire. In one of these tests the gun in which the cartridge is fired is equipped with an electrical arrangement which breaks a current when the firing pin strikes the primer. This releases the rod as described in the velocity test. When the shot charge leaves the muzzle of the gun, another wire connection is broken, releasing the weight.

This weight, as we have seen, operates a lever which scratches the falling rod. The distance the rod falls is translated into time as described in the velocity test and the time between the striking of the primer and when the charge leaves the muzzle is determined.

Another type of machine has been developed to test for hang-fire. This consists of a machine gun firing 250 shots a minute. In front of this gun is a disk revolving at 1,000 revolutions per minutes. This disk has holes at measured distances and the bullets must go through these holes as they pass the muzzle of the gun.

In other words, the gun is so synchronized that the slightest "hang-fire" on the part of the cartridge would result in missing the holes and hitting the disk. This test is similar to the actual conditions which occur in aeroplane guns, where the gun is synchronized with the propeller blade. This most rigid test was constantly being employed to test certain military ammunition, viz., "30 Gov't '06 cartridge" of which this company furnished over 500,000,000 rounds.

"Hang-fire" may not seem very important to some of us, but it is of vital importance. A slight hang-fire will probably mean a "miss" on the target, but far more important than this—a "hang-fire" may result in a serious accident, as the shell is liable to go off while being or after ejected from the gun.

The company we are visiting discarded the sulphur type of primer years ago and had perfected what is known as the lead sulphocyanide type of primer. This primer was later adopted by the U. S. Government after exacting tests, and was used in almost all of the Government ammunition. These primers were furnished in large amounts to other cartridge manufacturers during the war and shells loaded with these primers gave the highest satisfaction. The same company also developed and perfected a noiseless primer for use in hand grenades. This primer was finally accepted for use in all hand grenades furnished the Government, and the war record of this company demonstrates the degree of perfection which had been attained in the development of its primers.

ACCURACY TEST.

The ammunition is shot in all standard makes of guns to determine its accuracy. This test is to determine the accuracy of the bullet's flight and involves the trueness of the projectile, evenness of load, etc. Usually groups of ten shots are fired, all of which must register within a certain small area on the target. This test is made on ranges which vary from 30 feet to 1,000 yards.

On these tests the area and uniformity of the bullet pattern are watched and if any lot of cartridges should show the slightest variation from a normal pattern for the distance at which fired, this lot would be quickly rejected.

PRIMER TEST.

Primers are tested for both *certainty of fire* and over-sensitiveness. By dropping a weight from a definite height upon the primer a shock equal to that given by an ordinary firing pin is imparted. Primers must go off under this shock. On the other hand primers are tested against *over-sensitiveness* by dropping the weight from a lower point. They must not go off under this impact.

From each lot of primers a certain number are taken every day at random and put through this test. Absolute perfection is thus assured—certainty of fire and freedom from over sensitiveness. Our frontispiece illustrates the primer-testing machine at work.

PRESSURE TEST.

This test is made with the idea of making sure that the shells and cartridges are so accurately loaded, with respect to the amount, quality and density of the powder, that they will always have a uniform pressure when fired. This test is too complicated to describe in an article of this length, but it enables one to determine the actual pressure which results when the shell is fired and is an important test in making perfect ammunition.

Testing the Breech Pressure

RECOIL TEST.

(Webley Field Proof Test.)

Shells are tested for the recoil, or kick, by firing them in a gun which has been placed in a swinging frame. When the shell is fired the frame in which the gun is placed, is swung back by the recoil and the distance it moves is recorded. This distance, by means of a table, is converted into the recoil.

The velocity of the shot after leaving the barrel is also tested, as in the velocity test mentioned above for rifles.

These tests are in the hands of expert ballistic engineers of long experience—and their persistent application to this company's daily production of cartridges and shot shells is responsible for the accuracy and perfection of the cartridges it puts on the market.

Twenty-five million test shots a year is quite a record—even for a company of their size.

Earthquake Frequency

A PRELIMINARY investigation by T. Terada of the frequency of different intervals between successive earthquakes. This is a new way of approach to earthquake distribution; the usual method being to count the number of occurrences in a chosen unit of time. Under constant tension various materials undergo a time effect proportional to the logarithm of the time and therefore this is taken as the independent variable instead of the time. The probability of y lying between y and $y + dy$ for statistics of several earthquakes resembles the Gaussian normal curve. Certain deviations may be explained if the probability of occurrence is dependent somewhat on the occurrence of previous shocks.—*Science Abstracts.*

Problems in the Utilization of Fuels–I*

Economic use of the poorer grades of Coal and Oils

By Raymond F. Bacon and William A. Hamor, Mellon Institute of Industrial Research, Pittsburgh, Penn.

THE most efficient utilization of our wealth of fuel supplies is a subject which is being accorded constantly increasing attention. Interest in this topic in the United States has generally been confined to the advocates of the conservation of our natural resources. The fuel supply is still abundant and in industry it has usually been found to be a more convenient policy to burn high-grade coal, or fuel oil, than to be concerned with the problems encountered in the use of peat, lignite, or some of the poorer grades of coal containing a high percentage of ash. It also frequently happens that, in some mining districts, a portion of the coal is regarded as refuse, and is either burned to eliminate it, used for filling, or thrown on the culm piles. The reserves of bituminous coal and lignite in the United States are immense, but the supply of some of the higher grades of solid fuel, such as coking coal and anthracite, may be exhausted during this century, and accordingly conservation of all classes of fuels cannot be over-emphasized in its importance. Indeed, it merits the most searching inquiry. This contribution presents a discussion of some of the most important engineering problems in the utilization of fuels.

THE UTILIZATION OF LOW GRADE FUELS.

The present period of commercial and industrial activity in the United States and Canada, in combination with the use of liquid fuels for automobiles and marine purposes, has accentuated the inadequacy of some of our commercially developed fuel supplies and has directed specific attention to the fact that certain known sources of fuel are being rapidly depleted. With the present limited development of our water powers and of our deposits of low-grade fuel, the American nation is dependent largely upon localized mining activity in the regions where deposits of high-grade coal and of petroleum are found. Large sections of the country receive their fuel supplies by long rail or water routes. They are often subject to delays from the shortage of cars, locomotives, or shipping; from congestion of traffic or from transportation, or as the result of miners' strikes. The cost of freight usually prohibits the transportation of any but the highest grades in coal for distant consumption. In such parts of the country there are often undeveloped deposits of low grade fuel which could be used locally, by several available methods, in connection with existing equipment. An accurate estimate as to the quantity of such fuel is difficult to obtain; but, based on the area in which it is found, the amount unquestionably, largely exceeds the supply of fuel now being commercially utilized.

This fuel has been classified into two divisions, viz., lignites and peats, and graphitic coal, such as is found in the New England States and in the Canadian Northwest; and, in addition to these comparatively undeveloped sources of fuel, modern methods of coal mining, together with the necessity for taking out the thinner veins, have resulted in an increase of mine-waste which is not turned to use, but which possesses utilizable fuel value.

The reason for the lack of development and utilization of low-grade fuels may be summarized as follows:

1. The cheapness with which the high-grade fuels could, in the past, be mined and transported to the markets.

2. The need of basic experimental and development work, which is required in order to utilize the full thermal efficiencies of such fuels.

THE USE OF LOW GRADE FUEL FOR STEAM GENERATING PURPOSES.

Important work has been accomplished in power-generating stations in the direction of increasing the thermal efficiencies of the higher grade fuels; but much more investigation remains to be carried out along that economic line, particularly in the utilization of the full value of the fuel at high rates of combustion. High rates of combustion are, especially in large power plants, of extreme economic importance, the capital investment being reduced in direct proportion to the rates of burning. In nearly all of the accepted types of boilers the efficiency of the absorption of heat at high rates of combustion is greater than that of the furnace in the actual generation of heat. This is particularly the case when the boiler equipment is supplemented by economizers or other means of utilizing the heat lost through high waste-gas temperatures. Owing, however, to the low specific heat of the gases, the heat loss due to high stack temperatures is not as great as is popularly supposed.

Low-grade fuel may be burned on grates in furnaces of special construction for each class of fuel, and special mechanical appliances (stokers and grates) are available for burning high-ash coal and lignite and also coke braize[2]. It is probable, however, that low-grade coal and lignite can be utilized more advantageously in pulverized form. Lump coal, when burned on the grate in a hand-fired furnace, usually requires about 100 per cent of excess air, although with the best types of modern mechanical stokers this excess can be considerably reduced. With most kinds of pulverized fuel 25 or 30 per cent of excess air is, however, sufficient, and, with proper attention, the amount needed may be even less. The resulting temperature of the fire is, of course, a limiting factor. Other factors having a bearing on this problem are the construction of the furnace, the proportion of heat radiated directly to the tubes, and the fusibility of the ash. Properly constructed furnaces and burners should be able to use any form of pulverized fuel which has sufficient carbon content. For the firing of steam locomotives, pulverized fuel offers a method which is worthy of serious consideration in all parts of the country where the use of oil fuel is not more economical; in addition, it furnishes a means of utilizing certain neglected solid fuels.

In the case of peat, and of bituminous coal rich in combined nitrogen, the value of ammonia as a fertilizer renders the by-product gas producer worthy of very careful consideration for larger installations. The gas generated may be burned under boilers supplying steam turbines or it may be used directly in internal-combustion engines.

Comparatively little has been done in America in following this line of European development. Possibly the higher cost of machinery in this country has caused our engineers to look askance at a type of plant which requiress a considerable initial investment. And, besides, the American farmer has not so far been adequately educated in regard to the advantages of fertilizer for the intensive cultivation of crops. Our chemists have ,however, been endeavoring to awaken the nation to the importance of the nitrogen industry; and the generation of large amounts of power in hydro-electric plants has been advocated for the special purpose of making synthetic nitrogen compounds. Why not recover the nitrogen content of our fuels before burning them? Why not invest the capital required for hydro-electric developments in by-product gas producer plants for electrical power generation? It may be argued that the recovery of ammonia from recent and projected installations of by-product coke ovens will be sufficient. The saturation point for the use of fertilizers in America is however, still far away.

ON THE UTILIZATION OF COAL-WASHER WASTE.

It is clear that one of the chief fuel problems of the future is to be that of utilizing low-grade fuels, such as peat, lignite, mine-slack, bone-coal, and many other waste materials which, at the present time, are being discarded as too low in combustible matter to be of economic value. Some progress has been made in this direction in Europe, where the necessity of conserving fuel supplies has been more keenly felt than in the United States. Peat, in particular, has been exploited in England, Russia, and other European countries, and has come to be regarded as a rather important power fuel. Peat usually contains a high nitrogen content and it is for this reason that it has found such comparatively wide use. The nitrogen is largely recovered as ammonia when the peat is gassified in by-product producers, and the gas is consequently produced at low cost.

Coal-slack has also found some application in Europe as a fuel for by-product producer-gas manufacture, but, owing to its comparatively low nitrogen content, it has not been widely used for this purpose. It is claimed by certain gas manufacturers in England that low-grade coals containing as high as 40 to 50 per cent of ash have been successfully gassified in by-product producer-gas plants. The first cost of plant and operating charges are, however, considered to be too great for the economic utilization of such coals per se in this country within the near future.

The industrial use of high-ash fuels has, in fact, demanded much more attention in Europe than in the United States; but, so far as known, no special effort has been made to utilize bituminous coal washer-waste, or other similar waste materials, running 50 to 60 per cent or more of inert matter. The purpose of this section is to present the results of an investigation which has been carried out by Dr. C. B. Carter, under the direction of the authors, in an effort to devise a suitable method for the utilization of coal-washer waste, or refuse. Although this waste material inexceptively contains too little combustible matter to be of direct value as a fuel, it readily undergoes spontaneous combustion in the large dump piles accumulating at the washeries and accordingly becomes a nuisance. The object of the work conducted at the Mellon Institute of Industrial Research has been to find an economic method of preventing or else abating this trouble. To this end, a number of possible uses for the material have been evolved, but in no case could serious consideration be given to these uses unless their practice would require a large daily consumption of raw material. The reason for this becomes evident when it is borne in mind that a big washery produces several hundred tons of refuse per day.

FLOTATION AS A METHOD OF RECOVERING THE COAL CONTAINED IN WASHER-WASTE.

It has been demonstrated by us that the combustible matter contained in coal-washer waste of all grades can be almost completely recovered by suitable oil-flotation, a concentration process which, as is well known, is widely used on ores. Recoveries of 70 to 90 per cent of the total combustible matter present have been made by us, the extent of the recovery being dependent upon the oil used, the size of the material, the degree of agitation, the method of grinding, etc. The ash content of the recovered coal has been found to depend upon several factors, such as the percentage of recovery, the method of grinding, etc.

If washer-waste is ground in such a way that the grains of coal are subjected to a rubbing or rolling action, the yield of recovered coal will be small and it will contain an excessive amount of ash. On the other hand, if it is crushed or ground in such a manner that the grains of coal are subjected to a minimum of this rubbing or rolling action, the recovery will be large and the recovered coal will be relatively free from ash. For the best results it has been found that the washer-waste should be crushed to pass a 48-mesh screen, the word crushed being here used in contradistinction to the word ground. The coal particles show the maximum floating properties when they are sharp, angular and lustrous. Grinding in machines of the disk-type destroys these physical properties, and the yield of recovered coal from refuse ground in this way is small and its ash content is high.

The amount of ash present in the recovered coal depends also upon the quantity of coal recovered. In general, it may be stated that the larger the recovery the greater will be the ash content of the recovered coal. If it is desired to increase the recovery from

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[1]It may be mentioned here that a peculiar situation exists in respect to Canada's fuel supply, viz., that, notwithstanding the enormous resources which Canada possesses in coal, over 50 per cent of the consumption is imported from the United States. The Canadian coal-fields are situated in the extreme east and in the western provinces, while the great central provinces of Ontario and Quebec, the principal centers of population, are more easily and economically supplied with coal from the coal-fields of Pennsylvania. Further, no anthracite coal occurs in Eastern Canada, and Canadians have grown dependent upon the anthracite output of Pennsylvania for that desirable domestic fuel, which is not only the main house-fuel in Manitoba, Ontario and Quebec, but is imported even into the Eastern coal districts of Canada. While such a condition of international trade attracts little attention during normal times, under conditions such as those which have been brought about by the Great War, the importance of the situation and its possibilities are fully realized. During 1917 Canada produced about 14,000,000 tons of coal, of which 1.7 million tons were exported; during the same year 15.5 million tons of bituminous coal and 5.3 million tons of anthracite were imported.

[2]On the utilization of coke braize, see Hamor, Coal Age, 11 (1917), 780.

ay, 70 to 90 per cent, it is necessary materially to increase the agitation of the pulp in the flotation cell, and the ash in the concentrate will be increased, as a consequence, from 20 or 25 per cent to 30 or 35 per cent. This is doubtless due, in part, to the greater violence of agitation, but is attributable, perhaps in main, to the fact that, even in the finely ground material, much of the coal is intimately bound to grains of slate which are carried over the walls of the flotation cell by virtue of the selective action of the coal for oils. With less violent agitation the buoyant action of air on the coal particles thus weighted down will not be great enough to carry them to the surface. Another factor which determines the ash content of the flotation concentrate, to a greater or less extent, is the percentage of pyrite in the washer-waste. Pyrite floats readily, and it is, therefore, evident that the ash in the recovered coal will increase or decrease proportionately as the pyritic content of the waste increases or decreases; it is probable, however, that this could be controlled by preferential flotation. In recovered coals showing 25 per cent of ash, from washer-waste containing 65 to 75 per cent of mineral matter, as much as 40 to 50 per cent of the total ash is generally attributable to pyrite alone.

Conservative estimates show a plant erected complete to handle 500 tons daily of ordinary bituminous coal washer-waste, and to recover the actual coal contained in it, will cost at a maximum $135,000; and a similar plant to handle 250 tons daily will not cost over $90,000. In the case of the first plant, it is computed that the coal can be obtained from 65 to 70 per cent ash refuse, to the extent of 75 per cent of the total coal present, in the form of dry 25 per cent ash concentrate, at a cost of $1.84 per ton. The same coal can be produced in the second plant at a cost of $2.00 per ton. If it is assumed that the recovered coal has a 32 per cent ash content, the recovery will be greater, and the cost of production becomes $1.45 per ton for the 500-ton plant and $1.58 per ton for the 250-ton plant. It must be emphasized that these estimates are only approximations, and it is quite probable that the actual costs of production would be much below the figures given. On the other hand, they are sufficiently reliable to indicate that it is doubtful whether oil flotation can be employed, at the present time, as an economic process for the recovery of the coal contained in such high-ash materials as washer-waste. The process is, however, also applicable to mine-slack, bone-coal and certain other high-ash fuels which contain a higher percentage of combustible matter than the usual washer-waste of today, and this use will undoubtedly receive early consideration.

Although oil-flotation may not be an economic process for the recovery of the coal in most low-grade fuels under present conditions, it will undoubtedly play a leading rôle in meeting prominent fuel problems of the future. The results of this research, therefore, constitute a reserve of knowledge until the time when it becomes necessary to utilize the various solid fuel wastes of the present.

REWASHING AS A METHOD OF RECOVERING THE COAL CONTAINED IN WASHER-WASTE.

It seems from the information at hand that intensive rewashing offers a satisfactory solution to the problem of recovering usable coal from accumulated waste. From the results of the above-mentioned inquiry it appears quite probable that washer-waste of the type described can be rewashed by up-to-date washing machinery and that the final refuse will not be subject to spontaneous combustion, as it will contain 85 to 90 per cent of inert material. The combustible matter remaining in the final refuse will be integral with the slate and widely disseminated, and, for this reason, should not be greatly affected by weathering. The concentrate or rewash will contain most of the combustible matter in the form of 30 per cent ash coal and it is estimated that this rewash can be produced at a cost of about $0.20 per ton. It could be employed either directly as a fuel for boiler firing, or admixed with low-ash coal, as a fuel for by-product producers. In the first-mentioned application it would be equal in heating value to bone-coal or mine slack of the same composition, and those fuels have been found to be quite satisfactory for boiler firing in plants where mechanical stokers are in use. In the latter case it would probably be necessary to mix it with an equal amount of good coal, in order to increase the nitrogen content to such a value that the recovery of ammonia would be profitable.

GENERAL CONCLUSIONS.

The most practicable solution of the problem of utilizing bituminous coal washer-waste economically would therefore seem to be to employ it as a fuel for the production of gas in a by-product producer-gas plant. In order that it may be used for this purpose, the ash content would have to be decreased considerably and the nitrogen content increased. There are two methods of accomplishing this. A sufficient amount of good coal could be mixed with the refuse to reduce its ash content to 30 per cent, or less, and the nitrogen content would, at the same time, be raised to approximately 1 per cent. This method would demand an enormous plant capable of handling at least 1,500 tons of coal per day. The second method would require a plant of about 500 tons daily capacity. It would entail the rewashing of 600 tons of refuse, from which would be obtained 150 to 200 tons of rewash containing approximately 30 per cent of ash. By mixing this rewash with sufficient good coal to produce 500 tons of fuel, and then gasifying it in a by-product producer-gas plant, the waste material could undoubtedly be economically utilized.

SHALLOW PILING AS A MEANS OF PREVENTING SPONTANEOUS COMBUSTION.

A number of methods of coal storage have been described in the literature. As the result of a study of these methods, it is believed that shallow piling could be employed as a means of preventing spontaneous combustion in washer-waste bings. The method would require the distribution of the material over a large area, in layers not exceeding a few feet in depth. The first layer should be exposed to weathering conditions for several months before the second layer would be laid down; the second should then undergo exposure for several months, before the third would be deposited, etc., etc. The very rapid weathering in the shallow layers would obviate serious heating when the pile reached greater depths. It may be noted here that the subject of the spontaneous firing of coal requires more inquiry from a fundamental standpoint; the entire process is essentially one of "surface combustion," but between the initial absorption of oxygen by the coal substance and its final expulsion in the products, water and carbon oxides, and entire series of complex phenomena may be involved. The points demanding experimental study have been indicated by Bone[2] and need not be mentioned here.

ON THE COMMERCIAL STATUS OF AMERICAN OIL-SHALES.

It is extremely important that additional supplies of liquid fuel be obtained—a problem which essentially resolves itself into finding suitable substitutes for petroleum products. Indeed, it is certain that this fuel problem will come more and more into the foreground; and if in any way it were possible to provide a supply for only a small proportion of the liquid consumed, it would be a most desirable attainment from the point of view of national economics.

Animal and vegetable oils are, of course, of too much value for a variety of other industrial purposes to find their way into the fuel market, where large quantities and low prices are essential. Wood and coal products—in particular, alcohol and benzene—can only be expected to relieve the motor fuel problem to a very limited extent; while peat oils do not give any indication of entering into the field in the near future, although the quantities of peat available in various parts of the world are sufficient to warrant some degree of local optimism.

Attention is accordingly being increasingly centered on shale-oil—a crude petroleum-like oil obtained from bituminous shales ("oil-shales") by subjecting them to destructive distillation in special retorts. Shale-oil has been found to be entirely satisfactory substitute for petroleum, affording similar results on refining; but the output of the product in Scotland, the home of the shale-oil industry and so far the only important producer, is not and never will be sufficiently large to make any serious impression on the fuel market.

Much publicity, a considerable part of which has been of a misinformative nature, has been accorded the enormous deposits of oil-shales occurring in the Uintah Basin ,which occupies the northern portion of Utah, south of the Uintah Mountains and extending eastward into Colorado. Perhaps an even greater area of oil-shales exists in a region of western Wyoming occupying the Green River Basin northward from the Uintah Mountains to Wind River Mountains. A third deposit of large size is contained 60 miles further east on the Colorado-Wyoming border. In addition, an area of approximately 2,500 square miles of oil-shales has been located in the central part of Utah near Manti; while near Elko, Nevada, on the Western Pacific Railroad, there occurs a small area upon which a number of locations have been made. Indeed, small areas of oil-shales up to 100 square miles in extent may be found in various localities all over the Rocky Mountain region. The deposits in the Uintah and Green River Basins are, however, the most notable, and certain areas of them constitute reserves which are in readiness whenever it is deemed expedient to establish a great American industry to supplement the failing supply of petroleum from the oil fields.

The oil-shales of the United States have so far received comparatively little technical attention, mainly because petroleum has been abundant. It may be mentioned, however, that, prior to the establishment of a petroleum-refining industry in Pennsylvania, the Mormons destructively distilled shale for oil near Juab, Utah; that numerous attempts have been made in the past to distill cannel coal, and that some experimental work has been conducted on the Devonian black-shale of the East. But no shale-oil industry has ever been established in America,[4] although various bituminous materials were distilled for the production of illuminating oil by a large number of "coal-oil" companies about 1860. The process followed in this short-lived coal-oil industry was very crude and ammonium sulphate production, found to be the necessary adjunct of the Scottish shale oil industry, was never attempted. Consequently, although a number of the coals and other substances used were of high grade, and merit investigation as to yield of crude oil, gas and ammonia according to present-day knowledge, it is not surprising that the refining of petroleum paralyzed the industry.[5]

The oil-shale of the Green River formation in northwestern Colorado and northeastern Utah is to be regarded as a fuel resource of great economic importance—a reserve which should now receive attention because the demand for petroleum and its products really exceeds the supply. The economic study of this shale was begun in 1913 by the United States Geological Survey, and the results of preliminary investigation demonstrated a promising yield of crude oil when the mineral was subjected to destructive distillation. More detailed examination along the north, east, and southeast sides of the Uintah Basin, in northwestern Colorado and in eastern Utah, has later indicated that, although the thickest and richest beds of oil-shale are exposed along the southern margin of the basin, nearly every section studied contains beds of shale more than three feet thick which will yield petroleum-like oil. In fact, in Colorado alone it has been estimated by geologists that there is sufficient oil-shale, in beds that are three feet or more thick and capable of affording more crude oil per ton than the average shale now mined in Scotland, to yield about 20,000,000,000 barrels of crude oil, from which approximately 2,000,000,000 barrels of gasoline might be obtained by the usual procedure in refinery practice. In Utah it is probable that there occurs an equal amount of oil-shale, just as rich in oil-forming material, or kerogen.

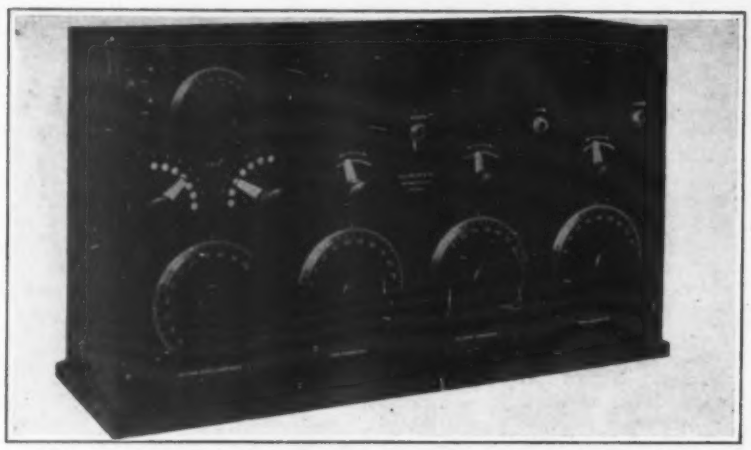
It is important to mention here that oil-shale cannot be profitably worked on a small scale and that the existence of a shale-oil industry in this country can only be assured by the most rational treatment of a sufficiently kerogenous shale to give a satisfactory production of an easily refinable crude oil. Numerous field tests as well as the laboratory findings of the authors point to the fact that the quality of the crude oil yielded by certain of the oil-shales of Colorado and Utah compares rather unfavorably with that of the product obtained from the oil-shale of the Lothians in Scotland; and it is also clear that, before any method for the distillation of oil from nitrogenous oil-shale can be regarded as an efficient process, the desirable production of ammonium sulphate (i. e., commercially satisfactory conversion of nitrogen into ammonia) must be secured. These problems can, no doubt, be solved in a suitable experimental-plant. The working of American shale will become as important an industry in this country as the distillation of carboniferous shale has become in Scotland, only after the manufacture has been based upon a retorting procedure developed in a unit constructed primarily in accordance with the best experience.

(To be continued)

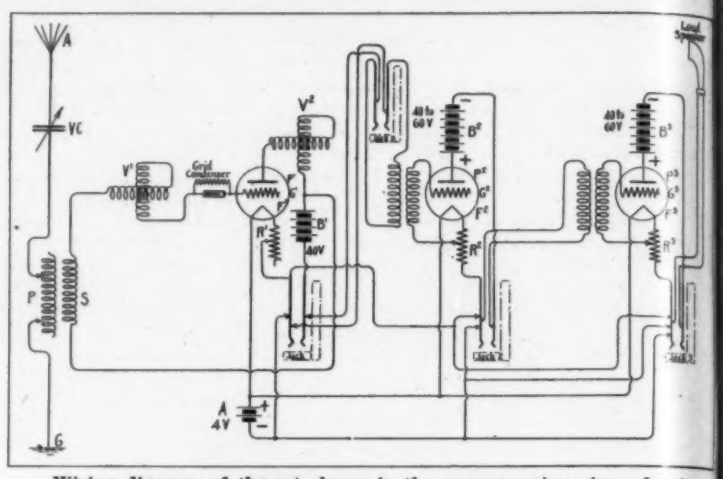
[2] "Coal and Its Scientific Uses," *1918*, 162.

[4] The oil-shales of Canada are not discussed in the present contribution. For information regarding Canadian deposits and their importance, see especially Ells and Hamor, Canada Dept. Mines, Report No. 55, Mines Branch, 1910.

[5] See Bacon and Hamor's "American Petroleum Industry," 1. 203-212 ;2, 807-844.



Short-wave regenerative receiving set with two-stage amplifier for long-distance work.



Wiring diagram of the set shown in the accompanying view, showing plug and jack arrangement.

Experimental Wireless Telegraphy and Telephony—VI*

Describing the Most Advanced Type of Receiving Sets, with Particular Reference to Post-Bellum Practice

By Louis Gerard Pacent and Austin C. Lescarboura

[Continued from Scientific American Supplement, No. 2279, September 6, 1919, Page 153.]

Any old-time radio amateur recalls the days of electrolytic and crystal detectors, when it was considered a great accomplishment to receive signals from stations several hundred miles away. In New York City, for instance, it was considered good work to hear AX—the station down on the steel pier at Atlantic City. To receive faint signals from Key West was a still greater accomplishment, and only the leading amateurs could boast of such a deed. But those were the days of relatively inefficient detectors and no amplifiers; today, with the use of a regenerative set, the amateur is able to receive signals from ordinary stations a thousand miles away, and with a two-step amplifier he is able to intensify the received signals until he hears the stations of Europe without great difficulty on an aerial several hundred feet long. Indeed, it is the vacuum tube and its wonderful application that has made possible long-distance reception as a regular thing rather than as a stunt.

VACUUM-TUBE RECEIVING SETS.

With the passing away of tuning coils and sliding loose-couplers, and the uncertain and clumsy sliders of the pre-war days of amateur wireless, there has come into existence an interesting line of neat, compact, and readily-operated apparatus in the form of complete sets. These sets range from the simple short-wave regenerative set to the large two-step amplifier sets for long-wave and long-range receiving. For the amateur who wishes to devote his time to receiving rather than to experimenting, the complete receiving sets are, of course, preferable. For experimental purposes the so-called unit apparatus, which is to say, separate instruments which are connected in any manner desired, are preferable.

The simple short-wave regenerative receivers generally comprise a rotary loose-coupler, two variometers, and the vacuum-tube controls. In the better apparatus the loose-coupler is provided with two switches for tuning the primary to a single turn. The coupling is varied by a rotary movement instead of by a sliding motion as in pre-war equipment. The antenna circuit consists of an adjustable inductance, which is altered by the two switches already mentioned, giving a fine adjustment of wave length. The secondary circuit consists of a coupling coil and a variometer, a combination which ensures the highest possible efficiency because of the absence of shunt capacities which are detrimental to the operation of short-wave receivers. The regenerative action, which is of the greatest possible degree, is obtained through the use of a variometer in the plate circuit. This variometer has the effect or purpose of reducing the effective resistance in the secondary circuit and feeds back energy into the grid circuit, thereby causing greatly amplified signals to be obtained.

In some receiving sets now being offered to amateurs the vacuum-tube socket is included, together with the controlling devices for the tube. The vacuum-tube socket is now made in the standard form of a length of brass tubing with an L-shaped slot for engaging with the pin on the side of the vacuum-tube base, and four spring contacts which make connections with the pins on the bottom of the vacuum-tube base. A resistance unit with relatively fine adjustment is used with the vacuum tube for regulating the voltage of the filament.

Some amateurs prefer the receiving set to comprise the tuning elements only, with the vacuum-tube unit as a separate bit of equipment. In such instances wireless apparatus manufacturers now offer short-wave regenerative receivers which comprise a loose-coupler, two variometers, and the necessary binding posts for connections. Such sets, of course, permit of varying the arrangement of the detector circuits and are therefore especially suited to experimental work. A slightly better type of receiving set includes an antenna series condenser so as to permit of compactness and high operating qualities.

AMATEUR SETS WHICH PERMIT OF TRANS-ATLANTIC RECEPTION.

Typical of the highest grade of amateur receiving apparatus is the set shown at the head of this page. This set comprises an antenna series condenser, grid variometer, telephone shunt condenser, wing variometer, loose-coupler, vacuum-tube detector, and a two-stage amplifier. The operation of this set is entirely rotary, while the vacuum-tube detector and amplifying units are controlled by a telephone plug and jack arrangement. The wiring of this set is shown alongside the photograph.

The plug and jack arrangement deserves special mention. By the unique wiring arrangement shown, the control of the detector and amplifying tube filaments, as well as the telephone and transformer circuits, is effected by merely inserting the plug in the jack corresponding to the desired condition. This feature affords an automatic control of the vacuum tubes, thereby effecting an economy in the life of the tubes and the batteries. With the plug in the first jack the detector tube only is placed in operation. In the second jack the detector tube is maintained in operation and its output is transferred from the telephones to the primary of the first-stage amplifying transformer, and the output of the amplifying tube received in the telephones. In the third jack the previous circuits are maintained and the second stage of amplification is obtained. By means of a special contactor, which is made an integral part of the telephone plug, the output of the second stage may be transferred to a loud-speaking telephone by inserting the plug only part way into the last jack. Another

*The first article of this series appeared in the Scientific American Supplement, No. 2270, dated July 5th, 1919. Copies of back numbers may be obtained as long as the supply lasts.

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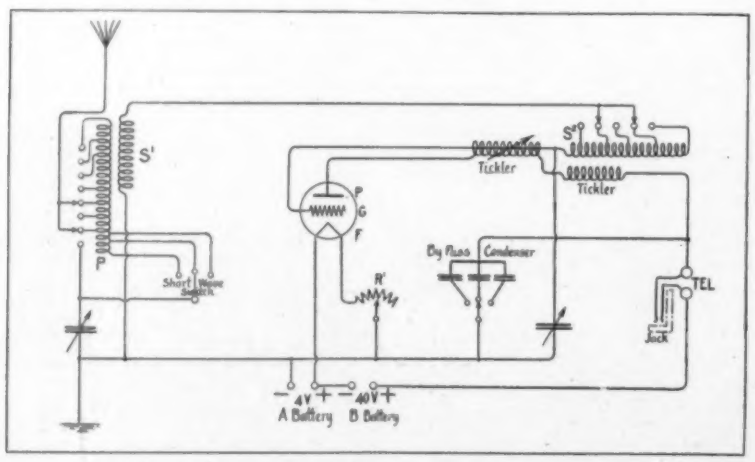
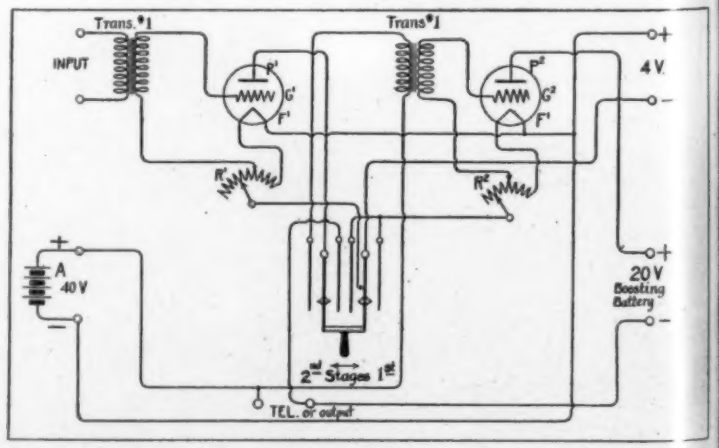
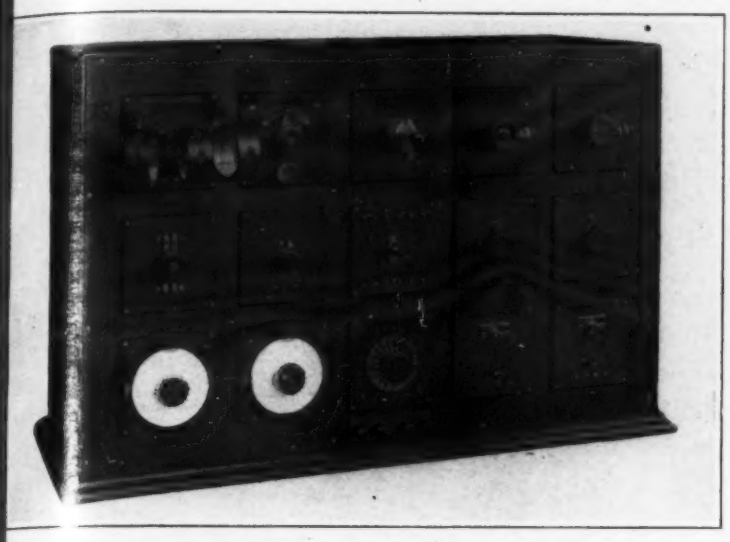


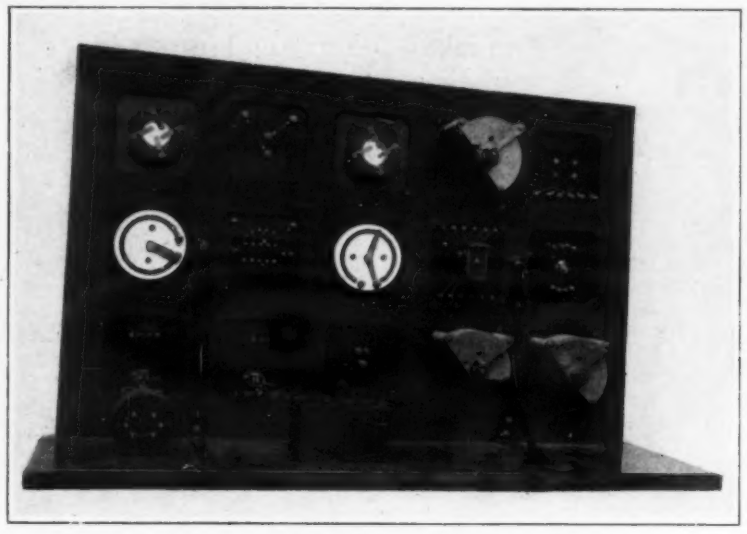
Wiring diagram of long-wave regenerative set shown on facing page.



Wiring diagram of an audio-frequency two-stage amplifier.



Front view of the unit system of making one's own receiving set.



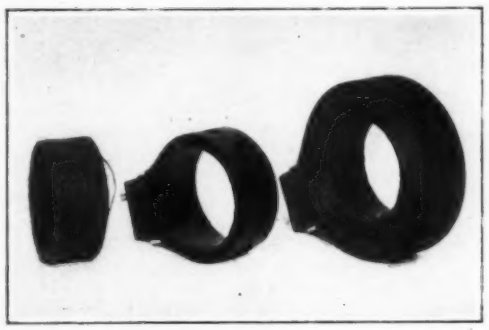
Rear view of the unit system of receiving set, showing mounting.

special feature of this set is the possibility of using the amplifiers in conjunction with external apparatus. This is accomplished by inserting a telephone plug which is connected to the output of the external receiver, into the detector jack on the set.

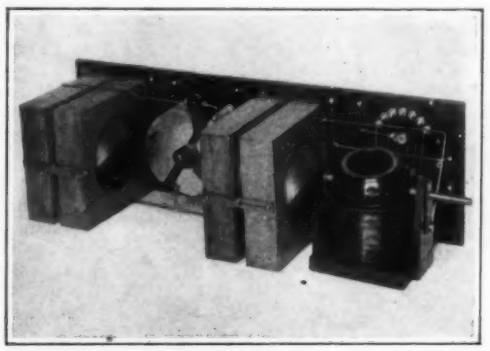
A typical long-wave regenerative receiver is shown in another view. This set comprises an antenna inductance, secondary inductance, loose-coupler, tickler, antenna condenser, and secondary condenser, together with short-wave switch and by-pass condenser, and the vacuum-tube arrangement. The combination of windings used gives the highest possible efficiency obtainable and permits of compact design. The antenna and secondary circuit inductances are almost identical. For the lower wave ranges, up to 2,200 meters, banked litz-wound windings are used. These windings are distributed in two, four, and six banks to obtain the proper coupling and inductance values. For wave lengths above 2,200 meters special "honey-comb" coils are used, these coils representing the greatest single advance in coil design ever made, and for the medium and longer wave lengths cannot be surpassed, according to wireless engineers. In cutting in inductance for increased wave length the preceding windings are included in the total, so that on the highest wave length range (10,000 to 20,000) all the inductance units are in circuit. The control of these inductance units is accomplished by two five-point switches with auxiliary levers and contactors for dead-ending the proper portion of the windings to eliminate harmonics. The design of the coupling and tickler coil windings is such as to provide the necessary regulation for all wave lengths from 500 to 20,000 meters, which is made possible only by the extreme accuracy of the design involving the relationship of the windings. As contrasted to the method of obtaining regenerative action in the short wave sets, which depends primarily on inductive loading of the wing circuit and the coupling action of the vacuum tube in the long-wave regenerative set, this action is obtained by the use of a tickler coil in the plate circuit in inductive relation to the grid circuit, which causes the feed-back of energy required. This latter is the most desirable for use in connection with the greater wave lengths because of the simplicity of the device itself.

AMPLIFIERS AND THEIR APPLICATION.

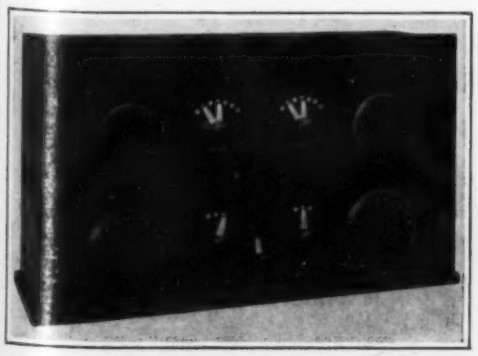
The action of the vacuum tube as an amplifier is left for another section of this work dealing with vacuum tubes in particular. Suffice it to say here that the vacuum tube lends itself to use as an amplifier; indeed, while acting as a detector or rectifier it is also acting as an amplifier. That is, greater oscillations are produced in the plate circuit for a given alternating voltage in the grid circuit than would be produced by the same voltage directly in the plate circuit. This explains why the vacuum tube is a more sensitive detector than the crystal detector, which acts as a rectifier only.



Inductance coils with special "honey-comb" winding.



Variometers, variable condenser, and rotary loose-coupler mounted in a typical regenerative receiving set.



Long-wave regenerative receiving set which tunes up to 20,000 meters.

The Marconi VT detector now being offered to amateurs is suitable for amplifying purposes; in fact, this vacuum tube is an all-round detector and amplifier. It is said that a two-stage amplifier and vacuum-tube detector using Marconi tubes gives 60 times the strength of signals that can be secured with a single detector tube; and because of the uniform properties of these tubes, all tubes may be operated from the same filament and plate batteries. This saves radio amateurs and experimenters the purchase of additional filament and plate batteries.

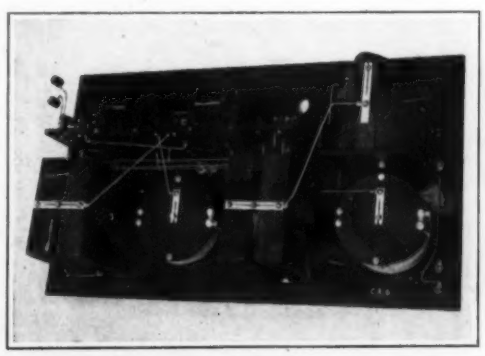
The most popular type of amplifier is the audio-frequency two-stage type, although some amateurs use the single-stage equipment. Audio-frequency amplifiers make use of small iron-core transformers for linking one step with the next, as shown in the accompanying diagram of a two-stage set. The use of a two-stage amplifier in connection with a vacuum-tube receiving set makes possible the reception of the faintest signals, and even otherwise inaudible signals, thus increasing the range of the station manifold. Indeed, the signals are amplified to such an extent that one can use a loud-speaking telephone in place of the usual head receivers. In the amplifier diagram shown, a special telephone cam switch with auxiliary contacts accomplishes the change from the "off" position to either one or two stages of amplification without necessitating other manipulations. The filaments, as well as the stage circuits, are controlled by this cam switch. The circuit arrangement permits of using a single filament and plate battery.

PANEL SETS MADE UP OF STANDARDIZED INSTRUMENTS.

What is a distinctly original idea in receiving apparatus for experimenters, students, amateurs and others, who desire to put their apparatus together in their own way, is the unit receiving set idea illustrated in two of the accompanying photographs. Standardized instruments in the form of interchangeable units are now being offered by a wireless instrument manufacturer, so that anyone can assemble his own receiving set in any way he prefers. Very much after the fashion of a sectional bookcase, one can add one instrument at a time to a receiving set, and can rearrange the set whenever desired.

The set, it will be noted, consists of parts and controls, each one of which is mounted on a small bakelite panel. These panels are provided with holes in the four corners for screwing to a latticed or cut-out backboard of wood or preferably a wall-board. In order to make up a complete panel receiver of the unit type system, it is only necessary for the purchaser to cut holes four inches square in the backboard, mount the units over these holes, and connect the apparatus together at the back of the panel, using any circuit he may prefer. The wiring is simplicity itself, as each unit is provided with connecting screws and a troublesome soldering iron is not necessary.

The amateur of limited means may start by purchasing a coil, crystal detector and condenser. These connected together will form a receiver, to which he may add at a later date, other coils and condensers to make his original set more selective and efficient. Aside from this feature, the unit system is ideal for the radio laboratory, since it affords a flexible method of arranging and rearranging apparatus to suit ever-changing requirements.



Rear view of short-wave receiving set shown at top of facing page.

Musk: It's Origin and Export*

Annual Slaughter of a Hundred Thousand Deer to furnish the World with Perfume

By Austin J. Clements

Musk is the chief and most valuable export of Tachienlu, Szechuan. Some thirty thousand ounces are disposed of annually, involving a turnover of Tls. 300,000. The trade is mainly in the hands of four large firms, but there are at least four score others of lesser degree engaged in it. The larger firms export to Chengtu, Chungking and Shanghai; the smaller ones confine their business to the local market. The trade is well established, and yields large profits. It has been adversely affected by the European War, and the disordered state of China, but should easily recover under normal conditions.

Musk is exported from other towns on the Chino-Tibetan border, such as Sungpan, Kuanhsien, Batang and Aduntze, but the largest quantity finds its way out through Tachienlu, which is the chief emporium for trade on the Eastern frontier. Musk is brought down to Tachienlu by Tibetan traders, by Chinese merchants or their agents in the interior, and by the hunters themselves. It comes in single pods or by the score; or again according to the firm which handles it, by the hundred and even the thousand pods. Supplies are drawn from a wide area. Even as far west as Jyekendo, musk is collected and sent down to Tachienlu; while Chamdo, Tengko, Shaeshu, Derge, Chantui, Kantze, Dawo, Litang, Hsiangcheng, Muli, Minyia, Yutong and Romedrango, all regard Tachienlu as their natural outlet. China is said be the chief exporter of musk to the world's market, and that being so, it is safe to say that the largest proportion comes out by way of Tachienlu.

The bulk of information which follows, has been gleaned from persons engaged in, or connected with, the musk trade in Tachienlu. Many of those with whom I spoke have never seen a musk deer dead or alive, but musk pods they have seen and handled in plenty. I must confess to the same disability, if such it is, but perhaps the deficiency may be condoned when it is recalled that the musk deer is a solitary and retiring animal, which naturally avoids the haunts of men, hence, to be seen and studied, it must be sought after in the distant mountain forests. At present I am chiefly concerned in writing about the musk trade as it is carried on in Tachienlu, or a study of the animal itself may be left for another occasion; but since the deer provides the musk of commerce, a brief reference to it may fittingly lead on to an account of the trade.

Wilson, "a Naturalist in Western China," describes the musk deer as a small animal, of stout and rather heavy build. Its hind legs are longer than the front ones, raising the rump above the level of the forequarters, giving the animal a hunched-up appearance. Neither sex has horns, and the long tusks and musk gland distinguish the male from the female.

The musk is secreted during the rutting season, by a skin gland situated on the genital organ of the male. The deer frequents the upper wooded country between 8,000 feet altitude and the tree limit 11,500-14,000 feet, according to the climate, where forests composed of spruce, silver fir and larch, with thin undergrowth and plenty of rocks obtain. It occurs solitary or in pairs, though in a small area, several may be found. It is very active and surefooted, traversing rocks and precipitious ground with great agility.

HUNTING.

The musk deer is hunted both by Tibetans and Chinese, by means of traps and snares; in some cases dogs and guns are used. The deer are tracked by their feeding and drinking places. They feed upon grass, moss and lichen. "Faier Scarf," a parasite which flourishes in the forests and festoons the trees, is a favorite food; also the leaves and acorns of the prickly oak, which may be found in the form of stunted bushes and fairly large-sized trees throughout Eastern Tibet. To the practiced eye of the hunter, marks of feeding by the deer on the bushes are easily detected, and where such signs are found, traps are set. It is thought by some, that the deer which feed largely on the scrub oak, produce better musk, hence they are much sought after in the places where the oak freely grows.

The deer is hunted at all seasons of the year, but the period when the musk is at its best is considered to be during the autumn and winter. There is no closed season, and the chase is carried on in spring and summer as well, but at this time the musk is thought to be slightly inferior in quality; however, in selling no distinction is made.

Marco Polo has a curious reference to the time of hunting the musk deer. He says: "The musk is obtained in the following manner: At the time when the moon is at the full, a bag or imposthume of coagulated blood forms itself about the imbilical region, and those whose occupation it is to take the animal, avail themselves of the moonlight for that purpose, when they cut off the membrane, and afterwards dry it with its contents in the sun. It proves the finest musk that is known." He adds: "Great numbers are caught, and the flesh is esteemed good to eat." Apparently methods have changed considerably since his day.

The traps which are set are designed to spear the deer and kill them. The snares take them alive by the feet. The latter method has more to commend it, because if the the hunter gives close attention to his work, better results are obtained. As the male alone produces musk, it is the male that is most sought after. Both male and female are taken in the snares. In the case of the latter, the hunter can use his discretion and let them go for further breeding, or retain them for their venison.

The same applies to young, immature deer, under three years old, which are not sufficiently developed to warrant killing. Not all hunters, however, are considerate and it follows almost as a matter of course that there is a great deal of indiscriminate slaughter.

From three years upwards the male deer produces well, and the quantity of musk found in the pod, increases each year of its life. Deer between the age of three and seven, are the hunter's objective. These bear small and medium-sized pods. Deer above the age of seven are scarce, the conditions of forest life not being conducive to such longevity! Occasionally older deer are caught, and yield pods of musk from one to two ounces in weight.

On rare occasions hunters secure what is known among the Chinese as *shoe teo hsiang*, i. e., snake's head musk, which is highly esteemed by the merchants, being considered of greater value than the ordinary musk. The name arises from the form which the musk takes on in the pod, as to some it resembles a snake's head in appearance. There are different theories as to the origin of this rarity, the more plausible being that the secretion in the preputial sac of the older deer dries up and hardens, assuming in the process a similarity to the head of a snake. This musk, having attained greater maturity and become highly concentrated, increases in value accordingly.

Other distinct forms are known and classified as *Chuyiuhsiang*, which is of the consistency of lard; and *chingyiuhsiang*, corresponding to vegetable oil in consistency. Both kinds are rare, and fetch a higher price than the ordinary.

A Yutong hunter told me that he recently caught a deer which produced a pod of the *chuyiuhsiang*, which weighed one ounce and a tenth (Chinese), and sold in Tachienlu for Tls. 28.

The number of deer killed every year to supply the musk market is enormous. A computation based on the quantity of musk exported annually, should give a fairly correct idea. The total export of musk from Tachienlu averages about two thousand catties a year. In the ordinary way, twenty-two pods of musk are required to make a catty. The pods vary in size and weight, but when large and small are mixed together, the average works out at twenty-two to the catty. On this basis the death of at least twenty-two male musk deer must be encompassed, to place one catty of musk on the market.

But for a comprehensive calculation this ratio is too low. If it were reckoned that thirty musk deer are killed to produce one catty of musk, we should be nearer the mark, for due regard must be paid to the fact that in snaring and hunting, both male and female, young and old, are taken indiscriminately, hence it is reasonable to conclude that for every catty (gross) supplied, at least thirty deer are killed.

And since the annual export from Tachienlu is in the region of two thousand catties, it follows that to supply the Tachienlu trade alone, there is a yearly slaughter of sixty thousand. And when the exports from Sungpan, Kwanhsien, Batang and Aduntze are added, the figures for the Szechuan-Tibetan border pass beyond one hundred thousand head. Yet in spite of this heavy exaction, the musk deer survives, and the quantity of musk brought down yearly to Tachienlu shows no sign of diminution.

This wholesale slaughter is nevertheless regretable. If the demand increases, reproduction may not keep pace with destruction, and there will be danger of extermination. By the methods now employed, the life of the musk deer is sacrificed to obtain the musk. Could not some method be found to extract the musk without destroying the life of the deer? It seems to me quite feasible. The preputial sac containing the musk is accessible, and has a natural opening on the outside, through which the musk might be drawn without injury to the animal. Those who are familiar with the ways of the musk deer say that it is the habit of the males to lie down in places exposed to strong sunshine and relax themselves, in which condition the musk sac opens by itself and the musk is exposed. If the musk deer were reared in semi-captivity, and suitable means employed to extract a small quantity of musk annually, some interesting developments might take place.

BUYING AND SELLING.

The purchase of musk in Tachienlu is a very difficult and onerous undertaking, calling for knowledge and experience beyond the ordinary. Adulteration is practiced extensively, and the powers of the buyer are taxed to their utmost to detect imposition. Even the most experienced buyers are subject to deception, and in a whole year's dealings it is considered a good average if eighty per cent of the musk bought can be classed as pure. The loss of twenty per cent is practically taken for granted.

In buying a consignment of musk amounting to several catties in weight, and made up of say over a hundred pods, it is customary for the buyer to spread the pods of musk on a table, or on the floor, and group them according to their size and weight. The pods are in their rough and dry condition, with an outer covering of hide and hair. Embedded in the hide is the musk pod, which in its dried state is seldom larger than a walnut. The practiced eye of the buyer runs over the musk spread out before him, and he divides the various pods from each other, placing those of approximately half-an-ounce in one group, those of three quarters in another, and so on, until the whole has been graded. Then with the aid of an abacus he calculates the total weight, and according to the current price per ounce, he bases an average per pod.

The use of scales to test the weight is not customary, although they may be resorted to by agreement. In the case of buying a score of pods that have been previously trimmed and dressed, testing by scales would be a better method; but in buying large quantities in their rough, dried condition, the amount of extraneous matter, such as hide, skin and hair, would preclude the certainty of close reckoning, and thus defeat the object. So ordinarily the buyer has to rely on his own judgment.

As an alternative the musk pods might be opened, and the musk bought and sold by net weight. It might be remarked in favor of this method, that adulterated musk could more easily be detected. Against this, however, it may be argued that musk in bulk, might more easily be adulterated. Be that as it may, the present custom of buying musk in the rough pod has been long established in Tachienlu, and is not likely to be changed, even though different methods prevail in other places. Nor might a change to the open method be profitable in the end, since after being removed from its natural covering, and frequently submitted for sale to one and another, the musk would be in danger of losing much of its strength through exposure.

When passing through Aduntze several years ago, I observed that M. Perrone, a French musk merchant residing there, followed the practice of turning out the musk from the pod after purchase, and storing it in special tin canisters for export.

In the hands of a foreigner this method is no doubt saft and effective, but I doubt the wisdom of entrusting it to natives.

*From *North China Daily News*.

In disposing of small quantities, the seller has the advantage. It is the custom of some persons to prepare the pods for the outside market, and then sell them locally. By this method the pods can be weighed with a good prospect of accurately gaging their weight and value. The method followed is to cut away a fair amount of the hide and hair, then soak the pod in water to bring it to its natural soft condition. In this moist state the pod is weighed, and the actual market value of the musk ascertained. The pod is then allowed to dry again, and in its dried, contracted state, offered for sale. Obviously the one who sells, by his previous testing of the weight, has a correct idea of the real value of the pod, and since his object is to get as high a price as he can, if the buyer in his mental calculation commits the error of rating the value of the pods too high, his offer is likely to be snapped up, and his mistake discovered when too late to remedy it.

Business dealings in Tachienlu are more or less open, consequently a knowledge of other people's affairs is quite common. Most of the merchants have a fairly good idea of the extent of the trade of their fellow business men; hence certain transactions such as the purchase of musk are generally known and freely discussed in business circles, even to the quantity bought and the price paid.

It was not unusual, therefore, in making inquiries about musk, to hear of a Tibetan trader from Rombatsa who had one thousand eight hundred pods for sale, and that the chief Chinese musk firm in the town had entered into negotiations for the purchase of the whole consignment. The price offered was said to be Rupees 27½ per pod. The pods averaged three-quarters of an ounce in weight. One thousand seven hundred of them were up to standard, but one hundred were below par, and the offer of Rupees 27½ was made on condition that the hundred poor pods were to be thrown in to boot. According to report the deal was not concluded, as the Tibetan trader stood out for a higher price.

When musk is sold in a Tibetan caravansery, the custom prevails of paying a percentage on the transaction to the landlord or landlady. Much of the business is done through their hands, it being understood that they assist in finding suitable buyers for the goods of their Tibetan guests, act as interpreters where necessary, and when their guests buy goods from Chinese firms on credit, the landlord of the caravansery nominally stands as surety. In consideration of these services as middleman, a regular commission is paid. Certain goods sold by the Tibetans are classed under the descriptive head of *mao-ho*, or hairy goods, comprised of wool, furs, deerhorns in velvet, hides and musk, the latter being included because of the tuft of hair attached to the pod.

The landlord's commission on musk sales is four per cent, and is charged to the buyer. Musk being a valuable commodity, the commission on a year's sales is considerable.

In so costly an article as musk, even the least adulteration successfully carried out is a lucrative undertaking, for musk is worth more than ten times its weight in silver; so the buyer has to be on his guard against all kinds of devices, and where his suspicions are aroused, he makes a thorough examination of the goods offered for sale, before he concludes a deal.

For the purpose of testing the quality of musk, the Chinese merchants use certain instruments specially designed for the work. The set consists of three articles usually made of iron, but occasionally of silver, according to the fancy and means of the person who uses them. The first is a thick and rather blunt needle, about four inches long, which is used to enlarge the natural opening in the pod, to allow of a sample being removed without injuring the pod. The second is a hooked needle resembling a button hook, which is inserted into the pod, and pushed over to the extreme edges, to probe these places, and detect any hard substance such as grain, which may have been secreted there. By means of the hook, the musk around the sides can be brought over to the middle for closer inspection. The third is a curved, grooved needle, used to extract a small quantity of musk from the pod, to be examined and tested.

Inquiries of musk merchants regarding the testing of adulteration, elicited the reply that there is no infallible test known to them. The consensus of opinion is that efficient testing turns on experience, and even the most experienced buyers are subject to deception.

In general there are half a dozen tests, and each merchant uses those which appeal to him most. Nearly all of the human senses are brought into play when full testing takes place; sight, smell, touch and taste each bear their part. In the sight test, general appearance and color are of importance. When a fresh sample is withdrawn from the pod and exposed to the air, if the musk is of good quality, it will expand and almost effervesce. Color indicates quality. According to local authorities, musk may be found in three colors, namely, yellow, yellowish red and black. Chinese consider yellow musk the best. Yellowish red comes next, black or dark musk is placed third. In the immature pods of a yearling, the undeveloped musk is said to be whitish and practically valueless.

The sense of smell is naturally exercised in testing an article whose chief value is in its fragrance. If the scent is rich and full, it passes as pure; but if some additional smell is combined with it, the presence of adulterated matter is indicated. In this connexion, fire readily exposes adulteration, for when burned, some of the things used to adulterate musk, throw off a strange odor, which, by those experienced in testing, can be distinguished from the smell of burnt musk.

The touch is also a fair test. Musk pods when trimmed and dressed, are sensitive to the touch. Foreign matter inserted in the pods has a tendency to harden, and will not easily yield to the pressure of the fingers, whereas pure musk is soft and impressible. A further test may be employed by placing a little saliva on the finger and thumb, together with a small quantity of musk. By this means adulterated musk can be worked into a paste between the finger and thumb, but pure musk will not mingle with saliva. It resists the action of water, and remains in its natural condition.

The sense of taste may also be employed, by placing a little musk on the tongue. Musk has its own peculiar flavor, which, though strong, does not wholly prevent the detection of any foreign matter that may have been mixed with it.

ADULTERATION.

The adulteration of musk is carried on both within and without Tachienlu, before and after arrival. Soon after the musk deer is taken and killed, a good opportunity is afforded for adulteration, for then the pod is soft, and the natural opening easily stretched. But these fraudulent operations are not confined to that time alone. Those fully initiated into the mysteries of the art, choose their own time and place, with, it is to be feared, only too much success.

Adulteration takes various forms, and numerous expedients are adopted to introduce an adulterant, and thereby increase the weight of the pod. By some, peas are used, also barley and grains of wheat. Comparatively speaking, these are among the simpler and better forms of adulteration, for they can be fairly easily detected, and when found, removed entirely without much difficulty or damage to the musk. Other more elaborate and deleterious adulterants employed are tsamba, mashed acorns, fried liver, pulverized beef, etc. These latter substances are more effective from the adulterator's point of view, because they can be mixed with the musk, and are more difficult to detect. Their effect upon the musk is of course injurious, and reduces it to an inferior grade, but does not spoil it altogether.

It is said that here in Tachienlu, there is a firm which is wholly devoted to the manufacture of false musk, and so successful is their work, that the production resembles real musk in every respect except smell! This absent quality is added by mixing a small proportion of real musk with the spurious article. The adulterant is sold surreptitiously in any quantity required, and is bought by unscrupulous musk dealers to increase the weight of small pods. Indeed some persons allege that no really pure musk is exported from Tachienlu, all being more or less adulterated.

THE BUSINESS OF EXPORTING.

The condition of the musk pod when it leaves Tachienlu, is decidedly different from its appearance on entering.

The pods are generally brought down in a rough dried condition, with an outer covering of hide and hair. To prepare the pod for the Shanghai market, it is first soaked in water until soft and plump, after which the redundant hair and hide are trimmed and reduced to more convenient proportions. The pods are then carefully packed in layers in small wooden boxes containing about ten catties, and despatched to the coast. When in their dried, contracted condition, the musk pods emit very little musk smell, the prevailing odor being of uncured hide, which surrounds the pod. After treatment by soaking, they give off a pleasant musk perfume.

Owing to the fact that pods are packed and transported in a damp condition, the export of musk is restricted to the cooler months of the year. From the first to the third moon the weather is suitable, because the temperature is low; but during the fourth, fifth, sixth and seventh moons the heat of the Yangtze route is too great to allow of safe shipment, so export is discontinued for that period. If musk is sent to the coast in damp pods, irrespective of weather conditions, the probability is that it will spoil in transit. The action of the great heat on the damp pods causes mould, and makes the musk useless. From the eighth to the twelfth moon export can be safely resumed.

IMPORT AND EXPORT DUES.

The musk trade is subject to taxation in the interior, at Tachienlu and along the route to Shanghai .The local impositions are fairly light, but taken in the aggregate, the numerous charges are considerable. . . .

THE USE OF MUSK.

Although it does not come directly within the scope of this article, a brief reference to the use of musk, may not be out of place. It is used by Chinese apothecaries in compounding medicine, especially for children. It is also much in favor among Chinese as a perfume. When supplied to the foreign market it is chiefly used for perfumes, either as musk alone, or in combination with other scents. As a base for general perfume it has the effect of making them more lasting.

OTHER USES OF THE MUSK DEER.

Whilst the musk pod is by far the most valuable part of the musk deer, yet its worth and utility does not end there. The venison is esteemed a great delicacy. Among other kinds of flesh, the Chinese place venison from the musk deer first. . . .

The hide also is of commercial value, being remarkable for its softness. It is in considerable demand in Tachienlu by furriers, who tan it, and use it freely in the composition of fox-skin gowns. Those who have paid any attention to the reverse side of a fox skin gown made by a Chinese tailor, will have noticed that the garment is largely composed of narrow strips sewn together. In making a garment of fox skins, the furriers contend that the fur is too thick to allow of its being used in large pieces, so the skin is cut up into strips barely half an inch in width, and narrow slats of bare deer skin inserted between. When the gown hangs down or lies flat, the abundant fur overlaps these bare spaces, and presents a normal appearance. The hide is also used by Tibetans to make small bags in which to carry their tsamba. Again, they cut it up into very thin strips for thread to stitch their leather work.

In the process of tanning the hide, the hair of the musk deer, which is coarse, brittle and hollow, is reserved for stuffing mattresses. In this department, the Tibetans have excelled themselves, and are able to produce small, folding mattresses, suitable for use on journeys, or for regular use at home, which, for neatness and resiliance, would do credit to a firm of modern upholsterers.

One specimen which I saw was about five feet long by two and a half broad, and folded neatly into four sections.

Electric Resistivity of Hardened Steels

Quantitative data and the rate at which the electric resistivity of hardened steel changes when the steel is reheated to a temperature as low as 100° C., and even when standing at ordinary temperatures, are given in a paper by E. D. Campbell presented before the Iron and Steel Institute in London. A brief summary of this paper follows:

The steels experimented with contained 0.57, 0.76, 0.945 and 1.05 per cent of carbon respectively. Bars were heated in a nelectrical furnace without oxidation to the desired temperature, and quenched in a large volume of water kept below 10° C. by means of crushed ice. After the specific resistance had been measured, one set of bars was placed in an electrically heated drying oven maintained at a temperature between 100° and 108°, and usually between 105° and 108°. They were kept in the oven for three periods of one hour, one period of three hours and one of six hours, their resistance being determined after each period of heating. The total drop in resistance after the 12 hr. tempering was 2.01, 6.50, 9.01 and 10.54 for the four steels. The other set of bars was placed in a cylinder at room temperature, and covered with oil to prevent rusting. Resistance measurements were made at various intervals; and after two years the total drop was found to be 0.47, 2.31, 3.32 and 3.53.—*Iron Age.*

Photo by California Redwood Association.

A GROUP OF 50,000-GALLON REDWOOD TANKS AT SAN DEIGO, CALIFORNIA

The Cooperage Industry*

Wood Suitable for Barrels and Tests that Barrels Must Undergo

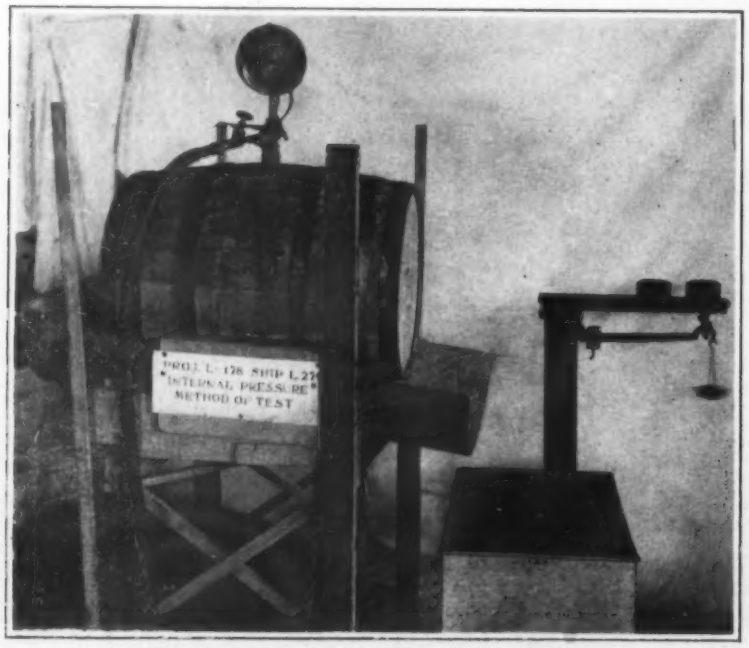
By Hu Maxwell

THE cooperage industry includes the manufacture of barrels, kegs, staves, heading, hoops, and other articles made of staves.

The growth or decline of this industry from year to year cannot be conveniently shown, because the government compiles statistics only every five or ten years, and the cooperage associations have never brought figures together except in the most superficial way. It is known, however, that the cooperage industry is fairly stable and does not vary much from year to year. The greatest influence recently has been the prohibition movement which has threatened to lessen the demand for barrels for spirituous liquors. Such barrels constitute a rather small part of the cooperage industry as a whole, and the diminution in the output of whiskey barrels will not greatly lessen the cooperage production in the country. Similar changes have taken place before in the cooperage business, as in the substitution of bags for barrels for cement, sugar, and flour; and pipelines and tankcars in place of barrels in the transportation of oil. In spite of such changes and fluctuations, the cooperage business has moved steadily on. That lost in one direction has been made up in another.

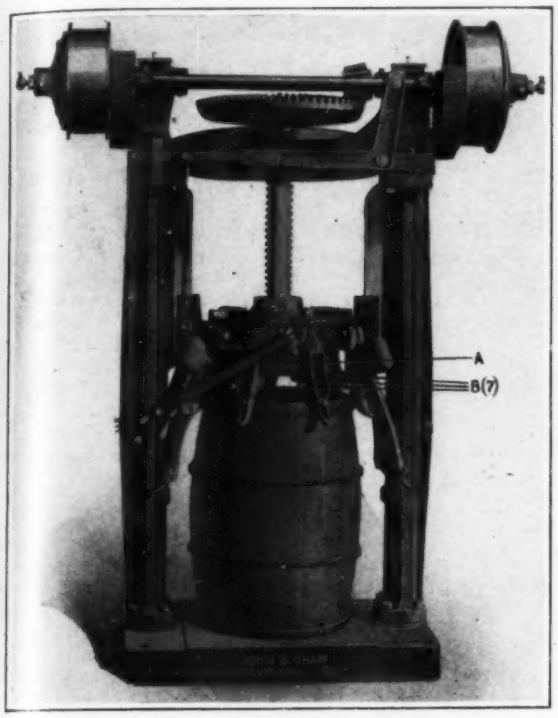
There are two kinds of cooperage, commonly distinguished as "tight" and "slack." Tight vessels are intended for liquids; slack for dry articles. Classes and grades come between the two extremes. The barrel that carries alcoholic liquors is considered the highest class of tight cooperage, while the vegetable barrel is typical of slack containers. The slack barrel end of the business is the larger, judged by quantity of wood required in manufacturing the product; but tight barrels demand a much higher grade of wood. The value of the slack stock used in the country is nearly fifty per cent. more than the value of the tight material. Nearly any wood is suitable for some kind of slack cooperage, but only a few are serviceable for tight.

*From *American Forestry.*

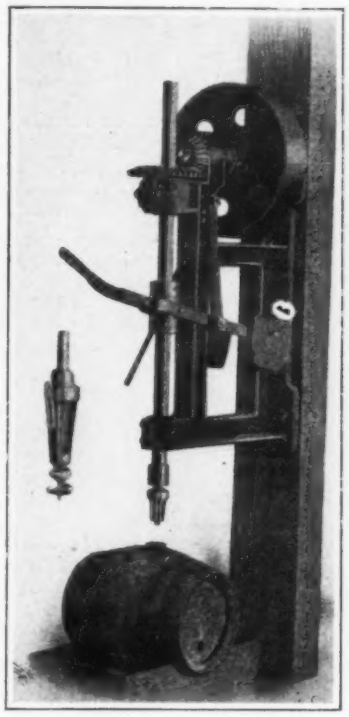


Testing the strength of a barrel by subjecting it to internal pressure

Determining how much bumping and tumbling a barrel will stand



The barrel trusser at work



Boring and bushing the bung

Heavy steel stave jointer

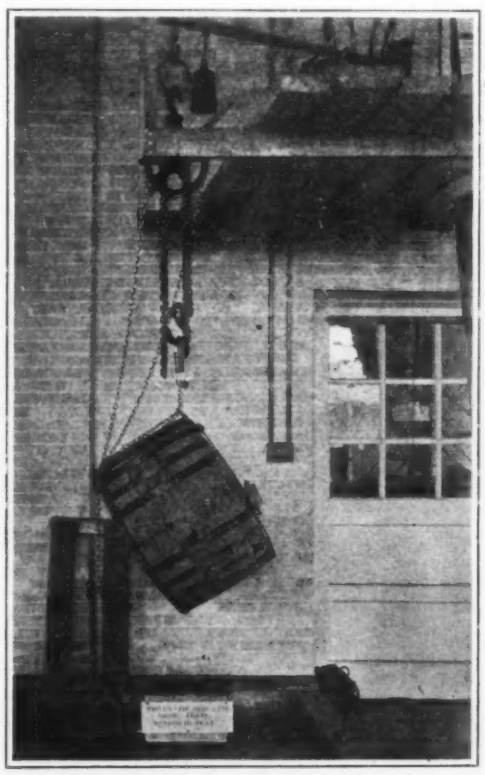
All cooperage whether tight or slack is made up of three parts, the staves, the heading, and the hoops. No barrel is constructed without all three of these, though certain patterns of veneer drums combine the staves and the hoops in the wooden sheet that forms the body of the vessel. No well defined line of demarkation separates the barrel from the hamper or stave basket, and sometimes it is not easy to say which is which. The manufacturing of the three parts often constitutes three separate industries, a mill or factory confining itself to one of them alone. The three parts are often brought together by the user who assembles them as the barrels are needed; but not infrequently a single factory turns out finished barrels which are then distributed to the users. The woods for the three parts are not always interchangeable. Heading woods may not be satisfactory for staves; that for staves may be objectionable for heading; while hoop woods are not wanted for heading or staves. Steel is being substituted for wood in cooperage, there being steel barrels without a particle of wood; but the most common substitution is wire or strap metal for hoops.

In the year 1909 there were in the United States 1,506 establishments producing slack cooperage. They manufactured 2,029,548,000 staves, 140,234,000 sets of heading, and 375,793,000 hoops. Usually sixteen slack staves, two sets of heading, and from four to eight hoops make a barrel, but great variation occurs in different kinds of barrels and kegs. The values in the United States in 1900 were, staves, $11,477,399; heading, $6,138,881; hoops, $2,578,845 The following list shows the woods from which the slack staves were made, and the number made from each:

Red gum, 416,570,000; pine, 306,621,000; beech, 268,237,000; elm, 245,172,000; maple, 133,255,000; chestnut, 93,290,000; birch, 78,897,000; basswood, 72,537,000; spruce, 72,219,000; ash, 71,705,000; oak, 66,675,000; cottonwood, 66,260,000; tamarack, 28,832,000; cypress, 25,673,000; tupelo, 22,500,000; sycamore, 17,831,000; hemlock, 10,376,000; cedar, 9,410,000; yellow poplar, 7,851,000; balsam, 6,037,000; Douglas fir, 5,165,000; willow, 3,287,000; all other, 1,128,000; total, 2,029,548,000.

Gaging pressure on the barrel's side

In holds of ships barrels are sometimes piled ten feet high and the lower ones are liable to be crushed.



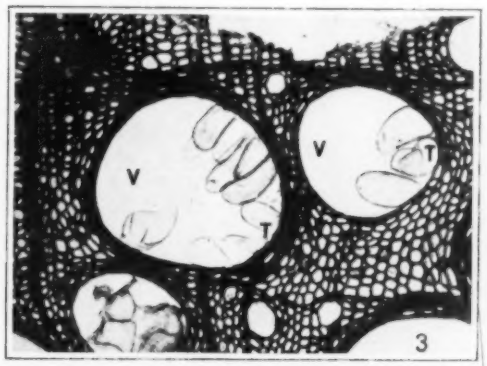
The chine test for barrels

The load is not applied squarely on the head nor on the side but on the chine, subjecting the hoops and staves to strain.

Room exists for considerable choice of wood for staves in slack cooperage, but not so much for containers of liquids. Flour barrels were once made principally of cottonwood staves, but elm has proved to be a good substitute. A white wood that presents a clean appearance is wanted, and it must be tough enough and strong enough to carry the load. It must be free from odor or taste that might injure the contents. The sugar barrel demands material of the same kind.

Red gum leads all other woods because it is abundant and satisfactory. The shippers of butter, lard, meat, and other wood products select the most suitable woods for their barrels. Custom has much to do with it, but not all; for it is easy to understand that a pine barrel might taint food with the taste of turpentine. The hardwoods are demanded in three times the number for slack barrels as are the softwoods; yet many commodities go to market in softwood barrels and kegs. Scrub pine is used for nail kegs and for containers of other small hardware. Timber which is fit for little else, and poles only a few inches in diameter, are sawed into staves.

All of the stave woods listed above are likewise used for heading, except cypress; but pine heading is consumed in twice the amount of any other, and beech stands second, with red gum third. The heads of various sizes are cut with special machines. Slabs from sawmills, are cut in rather large quantities into heading, and by combining a slack cooperage operation with lumber production, better utilization of the wood is secured. The coopers use the waste from the sawmill. Short and defective logs can be worked into staves and heading. Michigan leads all other states in slack cooperage production.



Why white oak does not leak

The pores are plugged by a growth called tylosis which is here shown in process of formation.

In the production of hoops, Ohio leads all other states, and is followed in the order named by Indiana, Michigan, Missouri, and Arkansas. Woods suitable for hoops are not so numerous as those for staves and heading. Toughness and strength are es-

sential in hoop woods, for the hoop must bend without breaking. Following is a list of hoop woods and the annual output of hoops from each in the United States:

Elm, 339,477,000; red gum, 9,877,000; pine, 8,321,000; birch, 6,051,000; beech, 3,560,000; ash, 2,020,000; oak, 1,160,000; maple, 731,000; spruce, 106,000; basswood, 30,000; cedar, 5,000.

Though these figures were published under government authority, those purporting to give the production of pine hoops have been questioned by manufacturers who do not believe that so many pine hoops are made. The unfitness of pine for hoops throws suspicion on the figures.

Two styles of wooden hoops are in use, the coiled and the straight. The coiled hoop is manufactured from logs, the wood being elm almost exclusively; and the straight hoop may be so made, or it may be shaved from little saplings called hoop poles, each large enough for one or two hoops. If two hoops are made from the pole, it is first split down the center and a hoop is shaved from each half. The making of hoops from hoop poles was one of the earliest wood-using industries of America, and the history of the business would read like a romance, though it deals with no very startling events. Some of the earliest hoops made in this country bound fish casks in New England, tar barrels in the Carolinas, and tobacco hogsheads in Virginia and Maryland. A number of woods were available for this commodity. In New England the long, pliant whips of white or old field birch (*Betula populifolia*) were the best, and most of them still wore the bark on one side when they went on the barrel or keg. Further south hickory held its ground as a hoop pole wood against all rivals; and very early in Virginia's history a writer sounded the warning that so many choice young hickories were being made into hoops for tobacco hogsheads, that future hickory forests would suffer. Frequently thirty or forty hoops were used on one hogshead; not all at once, but it was the custom to cut off the hoops and expose the tobacco to view whenever a prospective buyer appeared, and afterwards replace the staves and put on new hoops.

The hoop pole business was once active in nearly all the eastern and middle western communities, and the name "Hooppole" is carried by more than one county to perpetuate the memory of an early flourishing business in this branch of cooperage. A number of woods, besides birch and hickory, are good for hoop poles.

Extensive use is made of barrels and kegs as shipping containers, and in some places they compete with boxes while in others they hold the field to themselves. The life of a barrel is put down at one year by the trade, but that is not enough. A majority of barrels are used many times. They begin as sugar or flour barrels, and are then sold to the farmer for shipping his produce to market. It may be said that they are returned to him several times, carrying potatoes to the market on the first trip, and tobacco or lettuce on the next, each cargo being lighter in weight than the previous one, owing to the weakened condition of the barrel. Finally the barrel may serve out its life work as a trash receptacle, and in the end can be used for fuel. Thus it may be said that a barrel fills as useful a career as almost any other manufactured article, and its life is much longer than a season.

The demand for barrels is constantly growing, because modern machinery has made it possible to make them for the trade cheaper than almost any other form of durable package. That it is the most convenient form of package has long been acknowledged.

The heaviest demand comes from the cement business, and flour ranks next, closely followed by sugar and salt. As containers for fence, staples, bolts, nuts, nails, and packages for roasted coffee, spices, crockery, fruits, and vegetables, they follow in the order named. Glass manufacturers, baking powder companies, liquor distillers, and candy, tobacco, and cheese packers are big users of barrels. The demand for barrels for molasses, oil, lard, and pork, is also enormous, while dry paint, glue, snuff, oatmeal, screws, castings, and general hardware articles annually increase the demand on the cooperage supply.

Some woods are waterproof, others are not. Alcoholic liquors and some oils will pass through the pores of some woods where water will not go. The wood of which a whiskey barrel is made may absorb a gallon of whiskey, without any passing through the staves and escaping. Some woods are so porous that barrels made of them will not hold water very long. Coopers learned by experience that certain kinds of wood made better staves than others, when the barrels were intended for liquid. It was wholly a matter of experience at first, but later the microscope helped to explain why some are proof against seepage and other are not. All wood is more or less porous. It is made up of hollow cells, connected one with another by small openings, all microscopic in size; but some of the hardwoods have openings much larger than cells. They are tubes running through the wood, up and down the trunk of the tree, and are called pores or vessels. Some of them, as in oak and ash, are large enough to be seen by the unaided eye, by inspecting the end of a freshly cut stick. These pores are responsible for the fact that some barrels will not hold liquid. It seeps into the pores and flows along them until it passes entirely through the staves and escapes. That is why wood with large open pores is not suitable for tight barrels.

White oak has always been considered the best for cooperage wood. Many years ago it was thought that no other could or should be used for certain liquid commodities, but others have lately come into use. Yet, white oak has large pores, and a casual observer noting that characteristic would conclude that it is not good for tight barrels, but experience shows it to be good. Though it has large pores which may be easily seen, they are not open. They are closed as a bottle is closed with a cork, and liquid cannot enter. The plugging substance, which is known as tylosis, is of a whitish color and is deposited in the pores by the wood itself, in the progress of the tree's growth and maturity. It occurs principally after the sapwood has changed into heartwood. Red oak's pores are not plugged. Therefore, red oak is not suitable for the best kinds of tight cooperage.

The condition of the pores, whether they are plugged or not, explains why fewer woods are available for tight than for slack cooperage. The following table gives the kinds and the number of tight staves made annual in this country from each of several woods:

White oak, 217,019,000; red oak, 30,619,000; basswood, 30,589,000; gum, 23,566,000; pine, 20,648,000; ash, 5,568,000; all other, 13,250,000; total, 341,250,000.

Only the best wood is used as barrels for alcoholic liquors; but some other woods will do for other kinds of liquors, such as brine for pork, vinegar for pickles, and for certain oils.

Tight barrels are of several sizes. The strongest, heaviest staves are for beer barrels and kegs. The staves are manufactured by several different processes and are named accordingly, as sawed, hewed, and bucked and split. The tight cooperage industry is well distributed over the country but is more important in some sections than in others, depending largely upon the available supply of suitable timber in the various parts of the country. The leading states in annual production of tight staves are here given:

Arkansas, 87,582,000; Kentucky, 45,694,000; West Virginia, 40,402,000; Mississippi, 39,052,000; Tennessee, 35,744,000; Ohio, 26,534,000; Missouri, 22,420,000.

The waste of wood in the manufacture of tight staves in the past has been very great, but it is not now so great as formerly, because utilization is closer, and material which would have been thrown away formerly is now converted into other products. Much of the finest oak of the country was cut for staves in past years. The makers of this commodity went ahead of lumbermen in new territory, and being first in the oak region, they naturally selected the best oak trees, took the choicest portions of the trunks, and rejected the rest. They made no attempt to use wood which did not split well, and the stave maker's verdict: "It won't rive," was final and consigned the tree to the waste heap. It meant the abandonment of an oak trunk which might contain 3,000 or even 5,000 feet of lumber. That does not often occur now, for a sawmill is usually within reach and what cannot be split for staves can be sawed for lumber, or the logs may be sent to a mill equipped to saw staves or heading.

It was once a common situation in forests where stave makers were operating, for the ground to be covered with refuse billets and bolts which were left to rot because they were not just what the operator wanted. The workmen had no compunction when they left on the ground enough oak to make a thousand staves. Good trees were plentiful, and the stave makers turned their backs upon heaps of slightly defective bolts and went to work with their axes to fell other trees. Even when the operator had no fault to find with his timber, he usually left twice as much on the ground as waste as he took away as staves. Families living near the stave operations in the forests often secure sufficient waste oak to provide household fuel for years; and most of it was of such high grade stuff that it would have passed inspection by any furniture factory, had it been sawed into lumber instead of being split and slaughtered in the process of stave making.

Staves were saleable at good prices at a time and in regions where no market for lumber existed, and for that reason the stave operator was in advance of the lumberman in new country. Little capital was required in making staves when the farmer owned plenty of good oak timber, could buy a crosscut saw for eight dollars, an ax for a dollar, iron wedges for a dollar, a froe for the same, and could make his own maul, mallet, and wooden gluts; and the fork of a log served him for a riving horse. Thus equipped, he was ready for business. He had few labor bills to pay, for he could do all the work without going outside of his own family for assistance. Some stave making is still done along similar lines, but not much. Oak stumpage now has value, and it is pretty hard to carry on the smallest operation without the investment of some cash capital. Less dependence is placed on hand labor than formerly and more in machinery; and machines are expensive.

Bungs and faucets are listed as cooperage though they are sometimes considered as belonging to the subdivision of woodenware which is regarded as a separate industry. The bung closes the opening in the barrel; a spile or spiler is a small plug for closing a vent in a barrel or cask; while a faucet or spigot is a contrivance for drawing liquids from a barrel. The manufacture of these small wooden articles requires more than 21,000,000 feet of lumber a year, ninety per cent of which is yellow poplar, which is the best bung wood known. It contains no hard and soft streaks, therefore it may be cut with a smooth surface, which insures a close fit without leakage. The wood is dense enough to prevent liquids from seeping through, but it imbibes sufficient moisture to swell the wood, insuring a still closer fit. Walnut and red gum have been used to a limited extent for bungs and are quite satisfactory. Bungs are cut by machinery from lumber an inch or more in thickness. A larger quantity is made in Cincinnati, Ohio, than in all the rest of the United States.

The faucet is seldom sold along with the barrel but is a separate article. It is made in many patterns and of many woods, among them being white pine, spruce, maple, birch, beech, red gum, redwood, chestnut, cedar, walnut, and rosewood. A superstition formerly was to be met with that the wood of which a spigot was made exercised an influence upon the liquid which flowed through it; and for that reason molasses should be drawn through a maple spigot only, beer through one of birch, and cider through one of applewood. The applewood spigot was strongly insisted upon for cider, and it has been currently believed that much applewood is still consumed in the manufacture of faucets for cider barrels. The superstition must have lost its power if it ever had any, for an examination of statistical reports of woodworking does not show the use of a single foot of applewood for faucets in the United States. Sailors along the Atlantic coast in early years insisted upon equipping their water casks with white cedar faucets because of the reputed esoteric purifying qualities of the wood. Fishermen from New England and Canada, who drank spruce beer while on the New Foundland Banks, saw to it that their beer was drawn through no spigot but one made of spruce wood.

Many small articles made of staves are commonly classed as woodenware rather than as cooperage, among such being pails, buckets, keelers, measures, tubs, tool-dishes, and piggins. These have bottoms but no heads. The exact definition is not very important, for cooperage is a term broad enough to include all of them. The making of cedar pails was once a very important occupation in and about Philadelphia, the materials being both the white and the red cedars of that region, and the makers were known as "the cedar coopers."

The Highest Village on Earth

A writer in a recent issue of *L'Astronomie*, calls attention to a tiny village in Kashmir, which holds the lofty distinction of being the highest on earth. This village, which bears the name Karzok, is located at latitude 32° 58' 0".90 North and longitude 78° 18' 13".95 East from Greenwich. Its altitude is 4556 meters or 14,946 feet. The village contains a few wretched stone houses and a small Buddhist monastery.

The So-Called Improvement of Lightning Rods

The Use of Metal Parts of Buildings As Conductors

By Prof. Dr. L. Weber

Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from the *Elektrotechnische Zeitschrift (Berlin)*.

THE basic principle of Franklin's lightning conductor is extremely simple. A metallic path is constructed leading from the ridge pole to the earth, providing a road by which the lightning may reach the latter and thus be kept from taking a more dangerous path through the house itself. In spite of this simplicity it has taken a century and a half for all prejudice against lightning rods to disappear, and it is worth noting that for generation after generation Lightning Rod Commissions named by scientific academies have been obliged to continue their activities in order to spread the knowledge of this useful device. The reason for this must be sought on the one hand, in the fact that considerable latitude is allowed with reference to details of construction as regards material, form, and arrangement; on this account disputes have arisen concerning one point or another with the unfortunate result that the matter was often entirely dropped. On the other hand, confidence in the lightning rod had been lost because too little care has been exercised in its installation, resulting in repeated cases in which shocks were felt and fires took place in spite of the presence of the lightning rod. Considerable neglect of lightning rods was the result. But when the statistics of the fire insurance companies were published during the 60's and 70's revealing the frightful amount of annual damage in Germany due to lightning, the matter was taken up by a number of influential physicists, Karlsten in Schleswig Holstein, von Bezold in Munich, Weinhold and Toepler in Saxony; these men urgently demanded an improvement of the lightning rod. Instructions and correct standards were published with the object of making it possible for any intelligent workman, even though without special training, to instal adequate arrangements for protection from lightning. A gratifying number of lightning rod manufacturers sprang up in many places. Unfortunately portentous consequences followed from the resulting competition, for it was erroneously announced far and wide—though sometimes in good faith—that a lightning rod which did not correspond in every detail to the prescribed regulations, was more harmful than useful. Naturally, therefore, each manufacturer claimed to be the sole possessor of a prescribed method of construction and uttered solemn warnings to prospective customers to avoid faulty systems in view of the increasing danger from lightning. Since the directions given by physicists and officials actually differed from one another in certain minor points, confusion became wide spread among the public, especially in those rural circles whose interest in the matter is greatest. Following the false dogma mentioned people felt it was wiser to do without lightning rods entirely than to run risks supposed to result from one not properly constructed.

This state of affairs in 1880 caused the Berlin Academy to announce at the instance of their most eminent physicists, namely, Von Helmholtz Kirchoff and W. von Siemens, that even a faultily installed lightning conductor nearly always lessens the danger of buildings being struck by lightning, since it secures a partial discharge of the electricity, and that it was an entirely unjustified procedure to give up the well-demonstrated protection to be derived from lightning rods through doubts as to the most advisable construction in matters of detail. For the purpose of further enlightening the public a special sub-committee of the Technical Committee of the Electro-Technical Society in Berlin was created shortly afterwards under the chairmanship of Wilhelm Foerster, whose function it was to deal with "Danger from Lightning." Other members of this committee were Von Helmholtz, Von Siemens and the present chairman of the said committee, Geheimrat Neesen. In 1886 the deliberations of this committee were published in the pamphlet "Die Blitzgefahr, Nr. 1" (Springer, Berlin). The essential requirements of a good lightning conductor were there stated in simple language suited for general comprehension, definite enough on the one hand not to arouse objections on the physical and technical side, and simple enough on the other to allow the instalment of a lightning rod or at any rate the supervision of the work by an intelligent layman. The details of construction and the measurements given were such as to allow sufficient latitude for adjustment to special cases. Various military and civil officials issued more explicit regulations, based upon these generally recognized principles, which still hold good without alteration; these more specific directions were adapted to the various sorts of buildings in question, but had the disadvantage of resulting in a certain amount of standardization. In order to suit all the various individual cases the general regulations were obliged to assure more than an ample degree of protection; this involved an excessive degree of protection in the average case, and a resulting necessary expense. Hence economic considerations threatened to furnish a new obstacle to the extension of the use of lightning rods. At the same time the false teaching concerning the risk encountered by the use of conductors not absolutely perfect continued to make itself felt. * * * The late Chief Councillor of Building Findeisen called attention to the fact in the valuable work from his pen which appeared about the end of the last century that if all existing buildings should be provided with irreproachable lightning conductors, the cost of such provision would amount to a far larger sum than the cost of the damage from lightning to be feared. Since it is not to be thought of, however, to leave human beings and the dwellings they live in unprotected, and since it must be a point of honor with technical men to protect mankind and human structures against the natural force of lightning, Findeisen recommended as great an extension of the use of lightning rods as possible, but advised, at the same time, that the cost thereof should be kept as low as possible. With great justice and much success he emphasized the point that those metal objects already present on buildings, such as gutters and water pipes, protective metal coverings, iron supports, etc., could be used either wholly or in part as conductors of lightning. Supported by the recommendations of the Berlin Academy referred to above, Findeisen advised still further saving where this was possible by omitting or modifying the more costly portions at the upper and lower ends of the conductor, such as unnecessarily high receiving rods, especially those provided with points made of the noble metals; furthermore, instead of the often recommended sinking of the end of the conductor into deep lying strata of water, he regarded it as sufficient merely to carry a single branch into the upper strata of the earth. He was supported in the latter view by the results of the experiments made in Schleswig-Holstein, which showed that the damp superficial layers of the earth often play a much larger part in strokes by lightning than the much deeper lying deposits of water in the ground, and for this reason may be preferable as a locality of discharge.

The Elektrotechnische Verein agreed essentially with these suggestions and at Strecker's instance published in 1901, through the "Lightning Committee" referred to above, a treatise entitled "Principles for the Protection of Buildings from Lightning." In this pamphlet the few unconditional requirements, in full accord with the earlier publications, were briefly summarized; special attention was called to the advisability of using metal objects already present. In general a free hand was left with regard to details of construction; it was made clear that while it is true that a higher degree of security can be obtained by a multiplication of receivers, roof conductors and earth contacts, yet a minimum number of these is sufficient to furnish a marked degree of protection to the building, and that in any case an increase of danger is never to be feared. It is far better to employ cheaper though less perfect protective devices than to retard the spread of their use by recommending necessarily expensive ones. These Principles were completed in 1913 by addenda called "Explanations," in which details of construction were described and those cases in which cheapness of price was of the first importance were were considered, as well as those in which the highest degree of perfection is demanded.

Of course care was taken that the recommendation for simplification should not be thought to imply "cheap and bad." It was also made clear that simplifications which are unobjectionable for some kinds of buildings are not to be considered in others. For example, the straw covered rural buildings in South Germany, which have the whole ridge covered with lead for protection, not merely need no special ridge pole conductor, but the receiving rods can be reduced both in height and in number, or in case of extreme necessity can be entirely dispensed with. In this connection the numerous Schleswig-Holstein experiments showed clearly that strokes of lightning can only be prevented upon broad surfaces crossed by wire, when the ridge of the roof is provided with receiving rods in such a manner that each point of the roof falls within the so-called "area of protection" surrounding a rod. The number and the height of the rods bear an inverse ratio to each other in this respect, and economy can be practised only when the most advantageous middle path is taken between a few very high rods on the one hand and a great many more low rods on the other.

It may be interpolated here that the conception of such areas of protection has often been unjustly criticized because it was not possible theoretically to calculate their size and their form. Geheimrat Neesen states that this defect is already by way of being remedied through the large-scale spark studies he carried on in Neubabelsberg. In the practical instalment of lightning rods this notion of the area of protection cannot be disregarded. The space required must be estimated and corrected later by favorable or unfavorable experiences. There is some justice in the esthetic objections preferred against the lack of beauty exhibited by the receiving rods. Unfortunately this objection can only be allayed when the architect designs to provide suitable substitutes through metal adornments of the ridge pole, such as weather vanes, ornamental knobs, lattice work, etc.

The overflow pipes leading from the gutters offer another possibility of economy, since they can be employed as a substitute for the rods leading downwards from the roof and they even offer an advantage through their large surface area. The saving is not very great, to be sure, and, furthermore, great care must be taken that the separate parts of the pipe fit well in order to secure permanent union or else they must be properly joined by having metal strips soldiered on at the joints. These conditions are not always easy to fulfil and in Schleswig-Holstein it was found cheaper, as well as more fitting, to erect at least one or two regular lightning rods and use the gutter pipes merely as accessory conductors.

In those cases also where metal parts in the interior of the building, such as iron supports, staircases, and the like are employed as substitutes for outside conductors, special care must be taken to have irreproachably good connections and to insure the absence of other possible paths of discharge, since otherwise the improvement aimed at might be just the reverse.

All these simplifications recommended from the economical point of view have been designated by the term the "Findeisen System." It must be remembered that these words do not refer to any special system based upon electrotechnical principles, such as the Franklin-Gay-Lussac system, with its enormously large receiving rod and the one stout conducting rod leading into subterranean waters, or the Melsens system which, following the proverb "divide and conquer" puts its trust in a multiplication of receiving rods, conductors and earth contacts, while at the same time diminishing the distance between them . . . the Findeisen constructions are devised mainly for cases where financial considerations are of weight. They are highly important in such instances, while in those cases, on the other hand, in which expense is no object or in which the best possible protection is the chief end, they are to be recommended only under certain reservations * * * It would be much more correct not to speak of the "Findeisen System" but rather of the "simplified lightning conductors" proposed by Findeisen, as is done by Professor Ruppel who has been of great service in furthering the adoption of Findeisen's suggestions.

It might seem a matter of no great importance which term is used, but unfortunately this is not the case. In those circles of the populace which pay only casual attention to principles the word "system" has come to mean the application of new physical principles, or, at any rate, new electrotechnical principles through which the original and accepted construction of lightning conductors is to be entirely overthrown.

It is seriously to be feared that the unnecessary and wrongful opposition thus occasioned may once more fan to flame the still smouldering embers of the prejudice referred to above, respecting the danger from imperfect lightning rods. . . . This almost incredible misconception has repeatedly made its appearance in official reports. It is even worse when the daily papers use the expression "improved" instead of "simplified" lightning rods. It would even be preferable to have an exactly opposite description except that this might create an unjustified obstacle to the acceptance of the Findeisen suggestions, which in their proper place are highly valuable. But a door provided with a simple bolt is not always to be regarded as an improvement over one provided with a safety lock, and the present case is analogous.

Vegetable "Plethora"

(*Continued from page 220*)

of the tree a circular trench which he leaves open until June and he mutilates the principal roots thus laid bare. As a result the tree will blossom abundantly and give a fine harvest of excellent fruit. A curious instance actually observed may be cited in this connection; this is the case of an apple tree which had been overthrown by a violent storm, leaving only a few of the strongest roots in an active condition. While this tree had been covered with fruit in June it blossomed again in August. The physiologic poverty, i. e., the lack of nutriment, produced this second flowering; thus the serious accident which so gravely injured the vegetative system exaggerated the powers of the sexual system. On some of the boulevards and avenues in Paris, planted with chestnut trees, a freakish phenomenon may be observed in August or September, consisting of trees which have already shed their leaves but are covered with fresh clusters of flowers as in April. The reason is that the trees are scorched by the reflected heat from the houses and they also suffer from a lack of water; their vegetative apparatus being thus compromised the sexual apparatus gets the benefit proceeding from this rupture of the equilibrium. The lilac may be made to blossom twice a year merely by stripping off its leaves in June; it will then flower abundantly in August or September.

An extremely interesting fact is the death of long-lived individual plants as soon as they have blossomed and borne fruit. This is a regular occurrence among many species of the bamboo (Bambusa) which live for many years producing subterranean stolons from whose nodes new stalks spring up; but after the plant has flowered and borne fruit it dies. At first glance it might be supposed that the plant has been exhausted by the loss of the substance required to produce flowers and fruit. But this is not the case. The explanation of the phenomenon is as follows: For a long period the individual plant was in a state of youth and reproduced itself without employing sexual means. Then having exhausted the soil in its vicinity it arrived at a state of decrepitude and, therefore, flowered. In other words it is not the act of blossoming which causes the death of the oldest plants but rather the senility of the individual which finally causes it to flower.

Thus far we have considered only plants which are perennial and even ligneous in character; let us now enquire how annual plants behave. These bear fruit only once and this the same year they are born. Sometimes their strife cycle extends over only a few weeks. They pass rapidly through the youthful, adult and senile states; they germinate, vegetate, blossom and bear fruit with great rapidity. It is interesting to enquire the manner in which a state of plethora will affect them. Will it retard or diminish their fertility? And will the said plethora have an accumulative influence during several successive years? No one has ever observed, for example, even a small percentage of malconformation of their pollen.

We may sum up the matters treated in this article as follows: Plants display two distinct and opposite tendencies, they are influenced by two different functions. The first is the vegetative life which maintains the existence of the organism by means of the organs of nutrition, and the second is the sexual function which occasions the birth of new individuals through generation by means of male and female organs. Whenever there is reproduction without fertilization we have merely a prolongation of the life of the individual. . . . Organs of sex are necessary for the production of new individuals. In the normal adult state these two functions balance each other. During youth the vegetative life is naturally in the ascendancy; in old age the sexual life gets the upper hand. Extraordinary conditions are capable of disturbing this equilibrium. A state of plethora always injures the sexual system, most often attacking the male sex; physiological poverty or starvation often produces the most profuse flowering. Annhal plants must be regarded from this point of view as being in a very stable state of equilibrium.

Prime Mover of High Efficiency—II*

(*Continued from page 219*)

power, overload and fuel consumption, with less weight and space for the power it develops, it can look forward with some confidence, now that it can pass through the severe school of the engine shops of the world, to an adolescence of great promise, and it would be unwise to say what may be the limit of its ultimate career.

The following passage occurs in the final chapter of "The Gas, Petrol and Oil Engine," 1916, Vol. II., by Sir Dugald Clerk, F.R.C.:

"There appears to be only one method open to further increase thermal efficiency in a practical way, and that is by using regeneration of heat in some form. The ultilization of the waste heat of the water-jacket and the heat of the exhaust gases to raise steam has become considerable. It has been already mentioned that about 2.5 lb. of steam per. b.h.p. has been obtained from the exhaust gas heat of large gas engines. Taking 10 lb. of steam per shaft h.p. as the consumption of a high efficiency Parsons steam turbine, this would add 25 per cent to the power of the gas engine without burning any more fuel. A brake thermal efficiency of 30 per cent would thus be raised to 37.5 per cent.

"With an engine giving so high an indicated efficiency as 40 per cent, the exhaust heat would be insufficient in amount to raise 2.5 lb. of steam per b.h.p., but if all the waste heat were collected from the jacket, piston, valves, and exhaust—amounting to 60 per cent of the original heat—then the 40 per cent would be increased to nearly 50 per cent on the assumption that the heat could be utilized in a highly efficient steam turbine. The combined brake thermal efficiency of such a regenerative gas engine would be about 43 per cent."

This is the method which has now been presented before this society. It pretends to be merely a condensed summary of many years of patient, arduous work, combined with an admirable audacity without departure from the recognized laws of thermodynamics by William Joseph Still. Confirmation by so high an authority as Sir Dugald Clerk that this appears to be the only "method open to further increase thermal efficiency in a practical way," forms a fitting ending to these notes.

Economy of Motor Sweepers and Trucks

Haulage of street material by motor trucks, and operation of motor-driven street sweepers and sprinklers have proved economical in Denver, Colo., according to a statement made by F. J. Altvater, highway commissioner, in the April number of Municipal Facts, published by the city. At the present charge for teams, the trucks hauling slag and gravel will pay for themselves in one year.

Motor trucks for hauling slage and gravel for street work show a material saving in cost, owing to the high prices and slow work with teams. In 1918, the daily cost for a team was $6 per day, which this year has increased to $7. A team will average three 1½-cu. yd. loads per day, making a cost of $1.33 per yard or $1.55 at the 1919 rate. Last year three motor trucks hauled from 5,540 to 5,930 cu. yd. each at an average cost of $0.766 per yard. This cost included repair, oil, gasoline, chauffeur, interest at 6% and depreciation. The depreciation charge was computed at 33.3% for the first year and 25, 20, 15 and 6.3% for succeeding years. Five motor-driven street-sweepers and a motor-driven flushing machine also effected a considerable saving over horse-drawn apparatus; but the sweepers were rather light for the service and their repair cost was very high. Two 2-ton trucks were purchased later to do the heavier sweeping, and as they are separate from the sweepers they can be attached to wagons and other apparatus and thus are kept in use for about 16 hours daily. The two new machines have displaced 10 teams.—Engineering News-Record.

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